CFTRI-MYSORE
1953
Seed crushing co

SEED CRUSHING COMPOUND & PROVENDER MILLING

By
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and
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FOREWORD

When it was decided by the Seed Crushing, Compound and Provender Manufacturing Industries to form technical evening classes for employees in these industries, some concern was felt because there was not a text-book available that dealt exclusively with these industries. Even if at the time anyone had been found who was willing to undertake the formidable task of writing and illustrating such a book, it was too late for the 1946-47 session.

The writer had just been co-opted a member of the North-Western Area Technical Education Committee when he heard of the foregoing difficulty. He promised and undertook to detach a member of his editorial staff to attend the classes at Liverpool and, with the co-operation of the two teachers, Mr. A. S. Moore and Mr. H. Moore, to report the lessons weekly in "Milling" and at the end of the session to reprint them in the more permanent form of a book. This explains the appearance of this volume, only a limited edition of which could be printed owing to the paper shortage.

"Milling" is proud to be identified with these industries in this way and to this extent, and the Editor desires to express his appreciation of the co-operation he has received from Mr. A. S. Moore and Mr. H. Moore, both of whom revised their lessons before these were prepared in their present form, and also to his Assistant-Editor for the personal interest he has given to the lessons and the book.

L. F. SHEPPICK.

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PART I

SEED CRUSHING

by

H. MOORE

CHAPTER I.

BRIEF HISTORY OF SEED CRUSHING

The practice of removing oil from fruit or nuts has been carried on in one form or another for more than three thousand years.

The earlier history of the industry might be centred around three broad geographical divisions :

(1) China.
(2) India.
(3) Mediterranean Countries.

China takes first place, since the earliest records tell us that soya beans were treated for oil production on quite a considerable scale. The machinery used was obviously of the most primitive kind, and in the more remote country districts, the ancient methods are still used.

Early Types of Machines

A description of those methods is of interest to those desirous of noting the manner in which the different countries tackled a problem which varied chiefly in the type of seeds obtainable for their purpose.

For the pre-treatment of the beans, a humble yet fairly efficient contrivance was used which might veritably be described as the ancestor of the Edge runner. Secured by a rude axle to a central pivoting post was a large, round millstone. The other end of the axle was attached to a bullock by means of ropes. The beans were laid out in a circle on the track travelled by the stone, while the bullock walked in a wider circle and propelled the stone over its course. When the beans were suitably flaked, the mass was placed into a porous bag and steamed for a time over a copper of boiling water. Having attained a suitably soft consistency, the mass was transferred to shallow, round bowls. The bowls were then placed three or four high in a wedge press.

The press was made of wood and consisted of four strong upright posts slotted for a few feet near the base. Through the slots, wooden cross beams were fitted top and bottom. Across these beams, on the inside, other beams carried the bowls of material for crushing. Pressure was applied by driving wedges into the slot above the cross beams by aid of large stones. The stones were hung ready for use by means of a rope from the top of each post.

India's efforts at oil production from seed are nearly as old as those of China. The seed used in this case was sesame. The problem here was somewhat different, sesame containing as much as 54% oil against 17% in soya beans. Moreover, the nature and softness of sesame is such that steady application tends to induce spreading of the material. It is natural, therefore,

that the approach to the problem would take a different form from that of soya.

The ganny mill became the chief means of processing.

The ganny (or ghannie) consisted of a large pestle and mortar. The seed was pounded in the presence of water until the oil escaped from the seed and was skimmed off.

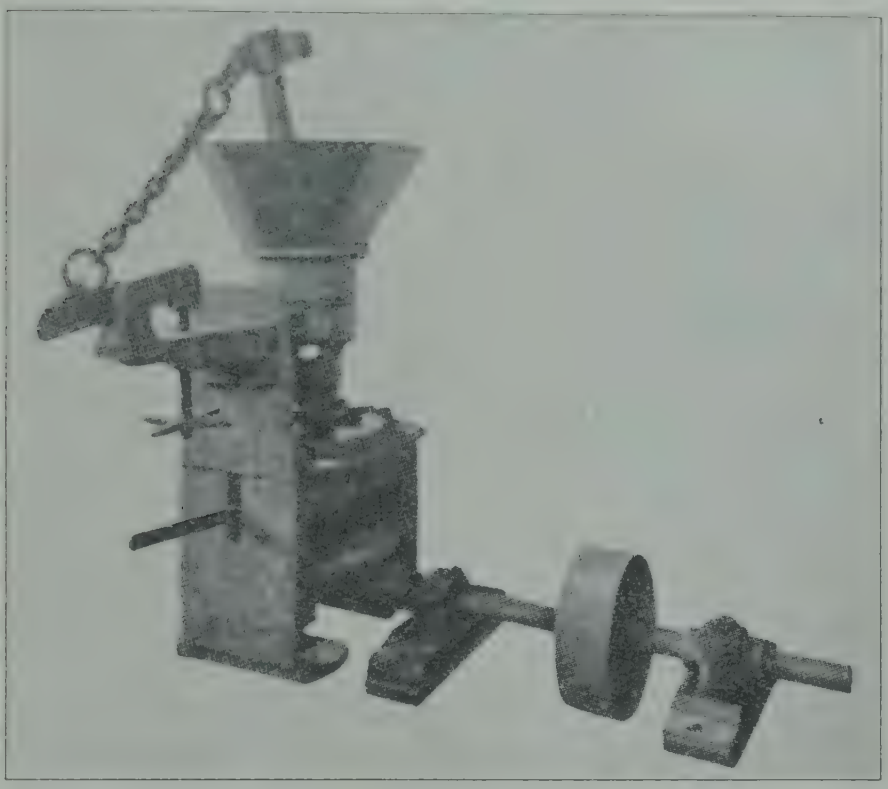


Fig. 1. Indian Ganny Mill

The modern ganny mill, though driven mechanically and much improved, is similar in principle to its ancient predecessor.

In Mediterranean countries, the olive appears to have occupied the place of honour in the realm of vegetable oil production. The lever press, followed by the screw press, was used in this case. The former consisted of a long wooden beam wedged under a rock at the lower end, and the fruit was placed in a bag under the beam near the fulcrum. The top end of the beam was pulled down as hard as possible, inducing a high pressure on the bag.

The screw press which, incidentally, was also used in China at a later period than the wedge press, was tightened by hand by a long lever and sometimes oxen were used for this purpose. All of these methods produced oil, but imposed serious limitations on the quantity of seed treated and on the efficiency of expression.

Little serious improvement took place in the development of the industry until the invention of the hydraulic press by Bramah in 1795.

The Need for New Materials

By that time, certain other fruits had become recognized as bearers of valuable oils, notably the coconut, which grew in abundance on the tropical sea-coasts. With the increasing technical improvement, the quantity of material processed increased, as also did the demand for oils, and men found it necessary to search for other oil-bearing fruit or nuts.

Ground nuts, linseed and rape were soon added to the increasing list of varieties, though many nuts and seeds containing valuable oil could not be used owing to the inaccessibility of the growing area or the difficulty of inducing the nuts to part with their oil.

Since all artificial illumination in those days was by candle or lamp, rape oil was in great demand on account of its suitability for burning in lamps. The better class oils, were, of course, used for edible purposes ; the poorer varieties being used to make a primitive type of soap.

Cottonseed, as a source of oil, came into the picture much later, and was only investigated for its oil value when the seeds discarded by the ginner after removal of the lint became such a nuisance that men scarcely knew how to dispose of them. Once started, however, the cottonseed oil industry made such progress that high prices were paid for seed that a few years earlier had no commercial value whatsoever.

Discovery of Oilcake as a Feeding Stuff

No mention has yet been made of the residue of the nuts after removal of the oil. The reason is simple enough. The seed crushers of ancient, and for that matter of comparatively recent times, were mainly interested in the oil produced, and the residue or cake, if not needed as manure, was either burned or thrown away.

It is understood that the feeding of animals on oil seed residue started by accident when a farmer who had been crushing some of his crop for oil noticed that his stock were munching contentedly at the pile of residue he had left in the field. This residue was duly investigated and found to be a very valuable feed for cattle, horses, etc.

It is sometimes said that the seed crusher is primarily interested in the oil and sometimes that he is more interested in the residue or cake. Where the oil industry is concerned, the high oil content seeds tend to be used, such as copra, palm kernels and ground nuts. Where cattle food is the main concern, cotton-seed, linseed, soya beans, etc., are crushed.

The final factors, however, are the availability and cost of the raw material coupled with the economy in processing, plus the relative demand for oil and cake reflected in the prices of these commodities.

Approximate Classification

Over 45% Oil		Under 45% Oil	
Ground Nuts (dec.)	48%	Cotton	19%
Sesame	54%	Kapoc	23%
Copra	63/70%	Soya	17%
Palm kernels ..	49%	Linseed	37%
Cocoa beans ..	50%	Rape	40%
		Sunflower	23%

CHAPTER II.

TYPES OF OILSEEDS AND NUTS

GROUND NUTS

Unlike the cereals, the most popular oil bearing seeds and nuts are grown in tropical or semi-tropical countries.

It is proposed to deal here with certain of the well known varieties of ground nuts, the chief producing countries of which are Africa, India, China, United States and South America.

The botanical name for ground nuts is *Arachis Hypogea*; they are also commonly referred to as earth nuts, pea nuts and monkey nuts.

It is generally accepted that ground nuts are truly indigenous to the American continent only, but since their introduction into Africa, India and China took place many years ago, the native varieties tend nowadays to be regarded as being indigenous to those countries.

Original Types

The original types grown in America, and subsequently imported into Africa and India, fall into two classes :

(1) Bunched—Stems erect and compact ;

(2) Running—Stems tending to trail along the ground.

Spanish Bunch.—The pods of this plant are small and usually contain two seeds. The decorticated nuts of this plant contain up to 50% of oil and are grown in America for oil production.

Virginia Bunch.—Large, white pods, the nuts having a lower oil content than Spanish bunch.

Virginia Runner.—Large pods, usually two seeded with good oil content ; the West African varieties are those of the runner or semi-prostrate type. These have since been introduced into India. The nuts cultivated in Madras are known as Coromandel and were derived from a strain imported from Mozambique, Portuguese East Africa. The original name given to this strain was " Mauritius " nuts.

Description

Ground nuts have a crinkly, fibrous shell or pod containing one, two, three or more nuts. The nuts are covered with a membraneous skin, the colour of which varies extensively from a deep, purplish red to a light, creamy brown.

The fibrous pod is called the shell, or pericarp ; the skin covering the nut being called the seed coat, or testa ; that part of the nut which is enclosed within the testa is called the flesh, or endosperm, and included in this endosperm is the embryo or germ.

Fig. 2. A Ground Nut Plant

Cultivation

To remove an erroneous impression, it should be understood that ground nuts are not, as their name implies, a root crop; that is to say, the nuts do not actually grow on the roots of the plant below the surface of the soil.

The plant grows to a height of about two feet, and after flowering, the young pods begin to form. The stems, on the ends of which the pods have formed, then bend downward and the pods are forced into the ground where they mature and ripen. Hence the name ground nuts.

The sketch, (Fig. 2) shows a typical plant of the bunch variety. It will be noted that the developed pods are commencing their downward journey, while certain of the flowers are still in blossom.

The seed nuts are planted in lines 2½ to 3 feet apart, with 9 to 12 inches between the seeds. The quantity seeded is usually about 40 100 lb. per acre, and this yields a crop of anything from 1,500 to 3,000 lb. per acre of undecorticated nuts, or 1,100 to 2,220 lb. of shelled or decorticated nuts.

The seed strains of ground nuts are usually obtained by a process of selection on experimental farms, and in recent years, much research work has been carried out in an effort to improve strains generally. Naturally, growers endeavour to obtain the highest quality of nuts for planting. The selection and production of seed nuts are often assisted by the crossing of indigenous strains with others imported for the purpose.

The growth and production of the ground nut crop depends to a large extent on the skill of the cultivator. Intensive weeding, and hoeing, for instance, are very necessary and these are carried out three or four times during the growing period. Neglect of this results in an excessive amount of extraneous seeds being included with a consequent lowering of the value of the crop.

Crop rotation also has an important bearing on the quality of the crop. Where crop rotation and manuring have not been carried out correctly, the ground soon becomes exhausted, resulting in poor crops with a low oil content. The crop rotation sequence usually follows the lines: ground nuts, maize, cotton, tobacco and one season fallow.

Rainfall also has an important bearing on production; if the ground is too hard and dry, the young pods cannot penetrate the soil and development is arrested. On the other hand, wet ground and excessive rains result in the soil being washed away from the pods and if this is not remedied, development suffers accordingly.

Harvest times and ports of shipment are as follows:

	Harvest Time	Port of Shipment
Madras (Coromandel Nuts)	Jan. Feb.	Madras, Cuddalore, Vizagapatam.
Bombay Nuts	Nov./Feb.	Bombay, Panjim.
West African	Nov.	Lagos, Port Harcourt, Bonny, Calabar.

Quality of Ground Nuts

When the seed crusher accepts a cargo of nuts, their value is assessed on the determination of the factors enumerated in the following order :

(1) Oil and moisture content of nuts.
(2) Free fatty acid in oil.
(3) General soundness of nuts.
(4) Freedom from extraneous matter.

Generally speaking, the factors stated are influenced by certain details relevant to their production and despatch :

(*a*) Strain and quality of seed nuts.
(*b*) Care in cultivation.
(*c*) Climate and geographical conditions.
(*d*) Storage, treatment and shipment.

Analysis of Nuts

The analyses are usually carried out on the nuts and husks separately. The whole seed analysis is obtained by arithmetical means as shown below and taken on specific analyses herewith :

	KERNEL	SHELL	WHOLE NUTS
Oil	48 %	1 %	35.78 %
Moisture	6 %	10 %	7.04 %
Albuminoids ..	28 %	4 %	21.76 %
Fibre	2 %	65 %	18.38 %

Amount of husk on whole seed 26 %.

OIL—WHOLE SEED

26 parts	@ 1 %	= 26	
74 „	@ 48 %	= 3552	
100		3578	= 35.78 % oil.

MOISTURE

26 parts	@ 10 %	= 260	
74 „	@ 6 %	= 444	
100		704	= 7.04 % moisture

ALBUMINOIDS

26 parts	@ 4 %	= 104	
74 „	@ 28 %	= 2072	
100		2176	= 21.76 % albs.

FIBRE

26 parts	@ 65 %	= 1690	
74 „	@ 2 %	= 148	
100		1838	= 18.38 % fibre.

Explanation of Analyses

It is proposed briefly to explain the meaning of the various items, but before doing so, another analysis, this time of the kernels only, will be given.

The nuts are known as Kandesh, and come from the Bombay district of India.

Oil (FFA 2.68 %) ..	47.23 %	Fibre ..	2.45 %
Moisture	4.63 %	Ash	2.23 %
Albuminoids ..	30.50 %	Sand	0.20 %
Carbohydrates ..	12.76 %		

OIL.—It is not desirous at this stage to enter into complex technical explanations. It should suffice, therefore, to say that the oil is a compound of glycerol and fatty acid and is a pale, yellowish, viscous liquid. The oil is removed from the nut by heat and pressure or by solvent.

MOISTURE.—The amount of water present in the nuts. This includes the natural moisture remaining in the seed and possibly additional moisture by absorption.

ALBUMINOIDS, OR PROTEIN.—Organic compounds composed chiefly of carbon, oxygen, hydrogen, and nitrogen. The chief function of protein in food is that of building up bone and tissue in the young of humans and animals and the replacement of worn tissue in the adult.

CARBOHYDRATES.—Compounds of carbon, hydrogen and oxygen; the hydrogen and oxygen existing in the same proportions as in water.

Starches, sugars, and dextrins are in this group of compounds. Carbohydrates are a source of heat and energy.

FIBRE.—Carbohydrates which are not easily assimilable as a food, the benefit of which may be outweighed by the energy used in digestion.

ASH.—Mineral or inorganic matter; the residue remaining after combustion.

SAND.—Siliceous matter; usually portions of soil from the growing area.

FFA.—Free Fatty Acid. Indicates partial degeneration of the seed. Excessive moisture or over-long storage causes some of the fatty acids to free themselves.

Advantage of Decortication Before Shipment

The shell is approximately 26 % by weight of the total undecorticated nut, but occupies about 45 % of the total volume.

The shell possesses a very low oil and albuminoid content, and it will be obvious, therefore, why it does not pay to ship this portion. For instance, a ship with a cargo space for 5,000 tons of undecorticated nuts would be able to carry instead 9,090 tons of decorticated nuts.

The nuts are partly dried either by kiln or sunlight before shipment; when kiln dried, the fuel used is usually the nut shells. Drying before shipment assists in the preservation of the nuts during the voyage or storage.

The moisture given up during drying also results in a further concentration of the valuable part of the nuts as this moisture can usually be replaced at some stage in the processing if used in compound cake manufacture.

COTTONSEED

The botanical name for cottonseed is *Gossypium,* of which there are several varieties. The following are perhaps the main types: United States (*G. Hirsutum*); Egyptian (*G. Barbadense*); Indian (*G. Neglectum* and *G. Arboreum*).

In addition to the seeds named, South America exports large quantities of cottonseed from such States as Brazil, Argentina and Peru. East and West Africa also produce large quantities of cottonseed and, next to the Egyptian seed, East African is the chief type imported into this country.

The Plant

The cotton shrub is cultivated for the production of lint, or fibre, the growing areas of the world being confined principally to within a belt of 40 degrees north and south of the equator.

The cultivated variety of cotton bush attains a height of three to four feet, and may be regarded as an annual or a biennial, the wild variety being a perennial.

Seeding and harvest times will vary with the country of origin. The American types are usually planted about March, the flowers appear in May, and the first bolls are usually ready for picking about the end of August.

The seeds of the cotton shrub are planted in rows about four feet apart, and during the early stages of growth the plants are thinned out to about one foot apart in the rows.

After flowering, the pods or bolls begin to swell to approximately the size of a walnut. Eventually, the pressure exerted internally bursts the boll and a white, woolly ball appears.

This woolly ball contains about 32 seeds about 9 mm. in length, the lint growing in a tight mass around individual seeds.

The seed lint is picked by hand and conveyed to the ginnery, and the pickers can usually collect about 100 lb. of seed cotton per day.

The product from the fields consists approximately of 33 per cent. lint and 67 per cent. seed. Most of the lint is removed at the ginnery and the clean seed is milled locally or exported to Europe.

The 67 per cent. seed referred to above will still contain a small amount of lint, say 6 per cent. Therefore, the original lint content of seed would be:

$$33 + (\tfrac{6}{100} \times 67) = 33 + 4 = 37\%$$

It is little more than 100 years ago that the seeds produced

were regarded as of any value apart from the quantity necessary to reproduce the plant.

Prior to the year 1834, the seed had virtually no commercial value and it was usually left to rot in the fields or creeks near the ginneries.

In the United States of America, this practice became so offensive that the authorities were compelled to inflict severe penalties on the ginning companies located within half a mile of towns for failing to dispose of the seed effectively.

Fig. 3. A Cotton Plant

Effective measures of disposal consisted mainly of burning the seed.

A few years before 1834, attention was first drawn to the fact that cottonseed contained a useful oil, but the technical difficulties which confronted the early experimenters proved so very great that little progress was made in the first few years.

Description of Varieties

The following is a description of the chief types of cottonseed imported into the United Kingdom :

EGYPTIAN. Long staple lint. The seed reaches this country as black seed. As the description infers, the lint which adheres loosely to the seed is removed easily and consequently the almost totally lint-free seed looks quite black in appearance.

This type of seed has two chief advantages. Its freedom from fibre means an increased density with a consequent economy in shipping space.

Egyptian seed, when ginned, will also flow fairly easily, which means that it can be stored in bulk in silos. Another advantage of this type is that the seed can be crushed without the preliminary process of delinting.

Owing to its brittleness, Egyptian cottonseed does not give the best results when decorticated, and is chiefly used in the production of undecorticated cotton cakes. The cake, however, is of good quality and is a lightish green in colour.

EAST AFRICAN. The quality of East African cottonseed is very constant, a characteristic which is useful to the seed crusher.

The lint content after ginning is usually 5 per cent. to 8 per cent. and for this reason, ginning and/or delinting is necessary.

The seed has a distinct advantage over most other varieties when decortication is desired. There are two main reasons for this. The prime condition of the seed makes for clean cracking in the hulling machine whilst the high albuminoid value of the meats makes the maintenance of guarantees a relatively easy matter.

BRAZILIAN. This type shows considerable variation in size, but in the main it is rather a smallish seed. The lint content varies from 3 per cent. to 6 per cent. and this is removed by delinting.

The seed is cleaned fairly easily and it therefore tends to be economical in the delinting process. The linters are of fair quality with a good staple length. Owing to its variations in size, Brazilian cottonseed is not numbered among the best types for decortication, although it makes a good solid undecorticated cake similar to the Egyptian variety.

SUDANESE. There are three types of Sudanese cottonseed : black, semi-black and woolly.

(1) The black type contains very little lint and is not unlike Egyptian except that the seeds are somewhat larger.

(2) The semi-black variety contains about 3 per cent. to 5 per cent. lint. The lint adheres only to the ends of the seed, it is easy to remove and gives a fairly good staple.

(3) The lint content of the woolly variety is considerably higher than that of the other two varieties, being from 9 per

cent. to 12 per cent. The lint is of good quality when light cuts are taken, but to obtain a clean seed condition, a large amount of delinting equipment is required.

The three Sudanese types mentioned have a large seed and produce a good type of oil and cake.

WEST AFRICAN. Cottonseed grown in West Africa falls into two main types, namely, woolly and semi-woolly.

Woolly West African seed is similar to East African cottonseed, except that it has a slightly higher lint content after site ginning.

The lints produced in England from this seed are of higher quality than East African when ginned, though the intensive delinting which is necessary to obtain clean seed often results in a discoloured lint of short staple.

Decortication produces a good quality cake of a slightly lower albuminoid value than that of East African.

The semi-woolly variety is not a very good type for decortication, though the lint is generally of a very high quality.

RUSSIAN. Very little Russian cottonseed finds it way into this country, and even before the war only small quantities were imported.

The lint content of this seed is very high, being 10 per cent. to 12 per cent. It is a large, sound seed of uniform quality and produces excellent lint, oil and cake. Russian cottonseed is also suitable for decortication.

INDIAN. This is a smallish seed and belongs to the woolly group. The lint adheres tightly to the seed, and that which is obtained after ginning is usually of poor quality. The smallness of the seed increases considerably the difficulty of decortication, and is not numbered among the best types for oil quality.

Lint Content after Site Ginning

The average lint content of the various types referred to above after site ginning is as follows :

East African	6 to 8%
West African	4 to 10%
Sudanese Woolly	10 to 12%
Sudanese Black	2 to 4%
Egyptian	1 to 3%
Brazilian	3 to 6%
Peruvian	3 to 6%

Site ginning means that the cottonseed has been ginned in the country of origin.

PALM KERNELS

Although for present purposes we are primarily interested in the kernels, since they are but a part of the fruit obtained from the palm tree (*Alæis Guineensis*), and since palm oil and

palm kernels are often confused, it is desirable that something should be known of the tree itself and of the fruits obtained.

Cultivation

The palm is a very tall and stately tree, and grows fifty to sixty feet in height.

In some countries, the tree grows wild and the fruits are collected wherever they can be found.

When cultivated, fruits from a mature tree are planted in nurseries, where they are left to develop for anything from two months to two years, according to the ideas of the cultivator. After this period, the young trees are transplanted into plantations, the distance between each tree being usually about thirty feet.

Six to eight years after planting, the tree will commence to bear fruit, and a healthy tree will continue to bear fruit for more than a hundred years.

Palm trees will yield an average of twelve bunches of fruit annually; the bunches may weigh anything from seven to fifty-six pounds and contain an average of two hundred fruits per bunch. The bunches are situated in the clefts formed by the branches at the top of the tree.

Palm Fruits

The palm fruits are about $1\frac{1}{4}$ inches long by $\frac{3}{4}$-inch wide at the thickest part. The outer surface of the fruit is smooth, but the flesh, or pericarp, consists of a mass of fibres thickly impregnated with a yellow fat. This fat is known as palm oil.

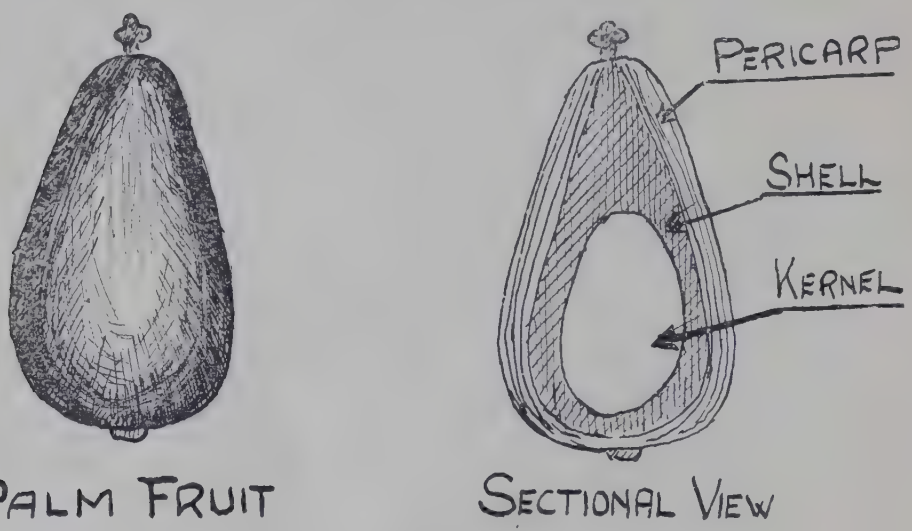


Fig. 4

The pericarp is fairly thin, and when it is removed, a hard, fibrous shell is exposed which looks rather like an undecorticated coconut. On cracking open the shell, the kernel is released. The kernel looks like a polished stone and may be black or brown.

Native Method of Processing

Because of their very soft character, the fruits tend to deteriorate very rapidly after gathering. For this reason it is necessary that they should be processed on the spot, and the palm oil obtained shipped to the United Kingdom in containers.

The nuts which remain after the removal of the pericarp will, if dried, remain sound for a considerable period. This is a distinct advantage, as it enables the grower to concentrate on processing the fruits while the nuts produced can be thrown on one side and treated at any convenient time between the seasons.

The treatment of the nuts consists of cracking the shell with either a stone or a hammer and picking out the kernel. The kernels are then bagged, transported to the coast, and shipped to the United Kingdom.

The method of removing the palm oil is as follows:

The fruits, which mature usually about March, are collected by native pickers who climb the tree with the aid of a rope sling and sever the bunches with a machete.

The bunches are gathered and the fruits plucked off, usually by women and children. The fruits are then boiled in a large copper.

When the fruits have been boiled to the required softness, they are then placed in another large copper, which serves as a pestle, and in which the fruits are beaten and knocked about with sticks. The effect of this treatment is to liberate from the inner nut the fibrous matter, or the pericarp.

On completion of this part of the process, the whole mass is placed in a trench. Water is then added and the mass well trodden by women and children. This treatment frees the oil, which rises to the surface of the water; the oil is then skimmed off and placed in containers. The shells containing the kernels are picked out by hand, shovelled into baskets, and carried to large dumps for cracking.

This method of processing is considered very wasteful; a good deal of the palm oil is lost, while that which is recovered deteriorates rapidly through the injurious effects of hydrolysis.

European Methods of Processing

In many places, the old native methods have now been superseded by mechanical processing which obviates the necessity of placing the fruit in water.

This method consists of removing the pericarp by means of a special machine. The machine comprises two flat discs between which the fruits are fed.

Each disc is fitted with knives, one set of which is stationary, the other rotating. The fruits are fed between these discs and into the spaces between the knives, whence the pericarp is split from the nut.

The pericarp which is removed from the nut by this action is ejected between the knives. The nuts are shot by centrifugal force through a series of holes in the outer lip of the casing and are collected separately.

The separated pericarp can then be treated by subjection to pressure in a hydraulic cage press, in much the same manner as other oil bearing materials are pressed. In this way, a superior quality of palm oil is obtained, as well as a greater yield per unit quantity of fruit.

Approximate Analyses

Palm kernels vary in shape and size, and it is difficult therefore to give the relative quantities of pericarp, shell and kernel. The following, however, may be considered as reasonable averages :

PALM FRUIT		PALM KERNEL	
Flesh or pericarp ...	35%	Oil	49%
Shell	50%	Moisture	5%
Kernel	15%	Albuminoids ...	9%
		Fibre	12%

The amount of palm oil in the pericarp varies considerably, and is sometimes as high as 70 per cent.; the average, however, is about 50 per cent.

The oil contained in the shell is considered useless.

The oil in the pericarp is a reddy, brown in colour, while the kernel oil is white and very hard. It might well be mentioned at this stage that if oil is hard, it is regarded in this country as fat.

Areas of Production

The tree is indigenous to West Africa and, undoubtedly, the largest proportion of the world's production is in that country.

Chief areas of production and ports of shipment are as follows :

CHIEF AREAS OF PRODUCTION	PORTS OF SHIPMENT
Gold Coast.	Accra, Sekondi, Takoradi.
Nigeria.	Lagos, Port Harcourt, Bonny, Calabar.
Sierra Leone.	Freetown, Sherbro.
Senegal.	Dakar.
Gambia.	Bathurst.
French Guinea.	Konakri.
Belgian Congo.	Kabinda, Banana.
Malay Peninsular.	Singapore, Penang.
Sumatra.	Padang.
Java.	Batavia.

COCONUTS

In one way or another, most of us will be familiar with the coconut. The extent of our familiarity, however, will probably date back to happier days when we would proudly carry home a coconut as evidence of our prowess at the "four-shies-a-penny" stall on the local fairground.

The coconut tree (*Cocos Nucifera*) is a tall, handsome palm standing as high as sixty feet in some cases.

Fig. 5.

A Coconut Palm, showing native picker ascending to collect nuts

The exact geographic origin of the coconut tree is not known, but it is thought to be in the region of the Pacific Islands. All the tiny atolls of the Pacific are fringed with these trees.

The tree grows abundantly on most tropical sea coasts between the latitude 25 degrees North and South of the equator. Salt water and sunshine are essential to the healthy growth of the coconut palm, and they undoubtedly thrive best on the sea coasts. Nevertheless, they are grown as far inland as 300 miles, but in these cases, salt water lakes or an extensive irrigation system are necessary.

In certain parts of the world, particularly in India, the coconut is chiefly grown for the production of toddy, a potent drink made from the juices of the nut.

The chief product obtained from the production of coconuts, of course, is copra, of which more will be said later. In addition to the production of copra, the hard, fibrous covering around the shell is used in the manufacture of rope, matting, brush bristles, etc. The name given to this fibre is coir.

Cultivation

For seed purposes, ripe nuts are selected from mature trees. After being kept for four to six weeks, the seed nuts are planted in trenches at about one foot apart. Prior to planting, ashes and salt are freely scattered in the trenches; these acting both as a manure and a protection against insects. The ashes are obtained by burning the husks. Animal manure is used very sparingly on account of its propensity for encouraging insects.

In the early stages of growth, the trees are transplanted at distances of thirty-five to forty feet apart to allow for maximum sunshine. The age at which the trees are usually transplanted is one year, but this may vary from anything between two months and two years. Trees commence to bear fruit, in some cases, when five years old, and will continue to bear fruit for as long as eighty years.

The yield of nuts varies according to the soil, climate, care in cultivation and type of nut grown. A normal, healthy tree will yield about 100 nuts per year, but in many cases, as many as 300 nuts per tree has been recorded. Taking an average of 100 nuts per tree, the crop would average something like six and a half tons per acre.

Insect pests cause untold damage to the coconut tree and are a source of great anxiety to the growers. These pests include wasps, beetles, and grubs which bore into the nuts; sometimes these pests bring about the complete destruction of the tree by boring their way into the trunk itself. Rats and monkeys also are not the least of the growers' worries.

Method of Collecting Nuts

As will be seen from Fig. 5, the nuts grow in clusters at the top of the tree. The native pickers climb the tree with the aid of the usual rope sling. The nuts are hacked off by the pickers and collected into convenient piles ready for splitting.

The hand method of splitting the outer shell consists of striking the nut against an iron spike. Using this system, a splitter can deal with as many as 1,000 nuts per day.

Drying

When coconuts are produced for the purposes of oil production, a special treatment is carried out before shipment. In this case, the nuts are sliced across and left in the sun to dry. The slicing may be done either by hand or by machine. A good opener may handle as many as 2,000 nuts per day; a machine, however, can handle up to 2,000 nuts per hour.

The machine used for slicing the nuts consists of three rotating, saw-like, circular knives. The knives are mounted axially and on horizontal centres. The angle between each knife is 120 degrees.

The nuts are fed on to the knives and cut neatly in three sections, after which they drop through the centre of the machine where they are collected for drying.

The complete sun drying period is about sixteen days. The effect of the drying process is to loosen the white, inner flesh from the shell. This shrinking of the flesh during the drying period increases the tonnage per unit volume and, therefore, results in economy in transportation.

The moisture content of the inner flesh before drying is usually about 50 per cent.; after drying, this is reduced to about six per cent.

Apart from the increased quantity per unit volume which results from the drying process, the reduced moisture content assists in the preservation of the flesh, and tends to assure a sound and wholesome product at the end of a long voyage.

As an alternative to the rather lengthy process of sun drying, the kiln drying process is also employed, the coconut shells being used as the fuel.

The kiln drying process is usually completed in one or two days, but against this advantage over the sun drying process, there are certain distinct disadvantages. For instance, the high temperature necessary for quick drying discolours the flesh, turning it from a pure white to a dull, yellowy brown, and the oil produced from this flesh is of inferior quality.

Grading and Analysis

Copra, which is the dried flesh of the coconut, is graded according to its treatment and resultant quality. The usual grades, in order of superiority, are as follows:

F.M.G.W.S. (Fine Merchantable Good White Sun Dried).
F.M.S. (Fine Merchantable Sun Dried).
F.M. (Kiln Dried). (Fine Merchantable Kiln Dried).

The following is an approximate analysis of copra :

Oil	63-70%
Moisture	5%
Fibre	2.25%
Albuminoids	8%
Carbohydrates	13%
Mineral matter	1.75%

Areas of Production

The chief areas and countries which produce copra, together with their ports of shipment, are as follows :

AREA OF PRODUCTION	PORT OF SHIPMENT
Ceylon	Colombo.
Malay Peninsula	Singapore, Penang, Port Swetenham,
Sumatra	Padang.
Java	Batavia.
Nigeria	Lagos, Port Harcourt, Calabar.
East Africa	Zanzibar, Mombasa.
Mozambique	Biera, Mozambique, Lourenco Marques.
India :	
Madras	
Malabar Coast	
Bombay	

CHAPTER III.

TARES, FOREIGN MATTER AND PESTS

The undesirable extraneous matter found in the raw materials of the seed crusher may be placed under the following headings : Tares, foreign matter and pests.

TARES

Although tares, to be strictly accurate, are weeds, it may be said for our purpose that they include any type of foreign seed found in a specific parcel of single seed.

Contamination may occur in one of two ways. The first source we may consider is that in which contamination occurs when two different types of oilseeds are shipped together in the same hold. In spite of careful stowing, a certain percentage of the two materials may easily become mixed by reason of burst bags, poor division walls, etc.

The safest method of ensuring that contamination does not occur in this way, of course, is to arrange the cargo so that each particular material is shipped in a separate hold.

The second source of contamination is by far the more serious, and is certainly the more difficult to avoid. This refers

to the presence in any particular parcel of material, of weed seeds which have grown alongside the true crop, or the seeds and nuts from trees growing in the vicinity of the crop.

The varieties and types of tare are extensive, and their presence causes varying degrees of difficulty according to the means that must be employed in separating them. The most serious tare, and the one which causes the seed crusher the most anxiety, however, is the presence of castor seed in ground nuts, cottonseed and linseed. This is due to the poisonous nature of the castor meat. In the case of linseed, castor can usually be removed by screening, but with ground nuts or cottonseed, the problem is more difficult.

Rape seed and mustard are often found in linseed and their presence is very harmful both to the oil and the resultant cake. Linseed oil is a drying oil, while rape is a semi-drying oil.

The presence of rape in linseed oil, therefore, would interfere with the drying property which is the chief characteristic of linseed oil. In general, all non-drying, or semi-drying oils like coconut, palm kernel, cotton and ground nut are equally harmful to linseed.

On the other hand, the presence of a drying oil in a non-drying type is equally harmful. The contamination involved can be detected usually by a determination of the iodine value of the oil.

The iodine value of an oil is a number which indicates its capacity for absorbing iodine. Each different oil has its characteristic iodine value. The higher the iodine value, the better the drying capacity. In the case of hard oils, like copra and palm kernel, the iodine value is very low.

IODINE VALUE OF OILS

Drying		Semi-Drying		Non-Drying	
Soya ..	124-133	Cotton ..	103-111	Ground Nut	85-98
Linseed	175-185	Kapoc ..	86-98	Rape ..	94-106
		Sesame ..	103-112	Palm Kernel	16-18
		Sun flower	127-136	Coconut ..	8-10

FOREIGN MATTER

The range of materials under this heading is enormous; their influence may range from innocuous to very harmful. Most foreign materials can, however, be removed fairly easily by screening or aspiration.

Most extraneous material is thought to be of accidental origin, but it is worth while mentioning that pieces of stone weighing as much as 33 lb. have been removed from the intake plant. When it is remembered that native labourers in the countries of production are usually paid on the weight of the materials they collect, and, further that, say, cottonseed weighs very light, it is obvious that a 33 lb. stone is a useful make-weight so far as the native labourer is concerned.

Foreign matter which may be placed in the accidental category can be divided into four groups as follows :

(*a*) Small animals (dead or alive), eggs, dead insects.
(*b*) Twigs, small stones, sand.
(*c*) Jewellery, coins, tools.
(*d*) Wooden bearings, pieces of string, cartridges, etc.

Animals or insects which may be quite harmless to the seed are often found in cargoes or stores. They probably find their way into the material either to make a nest or as a source of food. On occasions, much to the consternation of the mill workers, snakes have been discovered in cargoes of ground nuts; eggs which may have been deposited by snakes, lizards or birds, have also been found.

A fairly common source of extraneous matter, particularly in linseed, are twigs of the plant from which the seed has been produced. These are easily screened out, however, and are not regarded as serious unless in large quantities.

Small stones cannot always be removed merely by screening and, if numerous, would require the use of an aspirator.

The seriousness of sand in an oilseed is largely a question of quantity. As in the case of twigs, sand is removed fairly easily.

Under the heading of jewellery, coins and tools, a truly amazing collection can be built up in an oil mill. This is undoubtedly due to the fact that much of the raw material

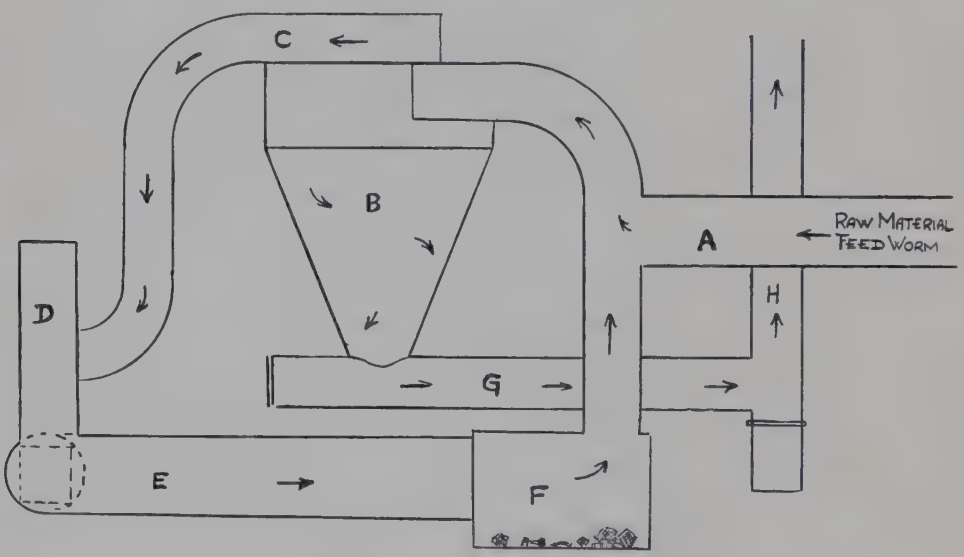


Fig. 6

The above is a diagrammatic representation of an aspiration plant for cottonseed. The raw material enters the air stream from the worm A.

Iron, stones, etc., drop in the chamber F. The cottonseed and air travel upwards into the cyclone B, where the drop in velocity causes the seed to fall in the worm G, then into the vertical worm H for processing. The air leaves the seed and travels up via the inner thimble of the cyclone into the pipe C, and thence to fan D.

The circuit is completed when the air leaves the fan and reaches the chamber F via pipe E.

comes from such places as Nigeria and the Belgian Congo, among others. In shipments from such countries may be found hunting spears or nose rings, tiny leather perfume bottles or wicked looking razors, ear rings, brass ornaments, nuts and bolts, rivets, and other things far too numerous to mention. In most cases, these ornaments appear to be made from old petrol tins, and baling bands and their removal is usually effected quite easily by means of electro magnets.

Where parcels of seed, particularly cottonseed, have been treated by machinery prior to shipment, it is not unusual to find discarded portions of bearings of the hard wood type, as well as nails, etc.

Most of the materials or objects mentioned can be dealt with satisfactorily by means of aspirators, screens or magnets. Very large stones, however, have been known to cause serious damage to intake plants before the separator plant is reached.

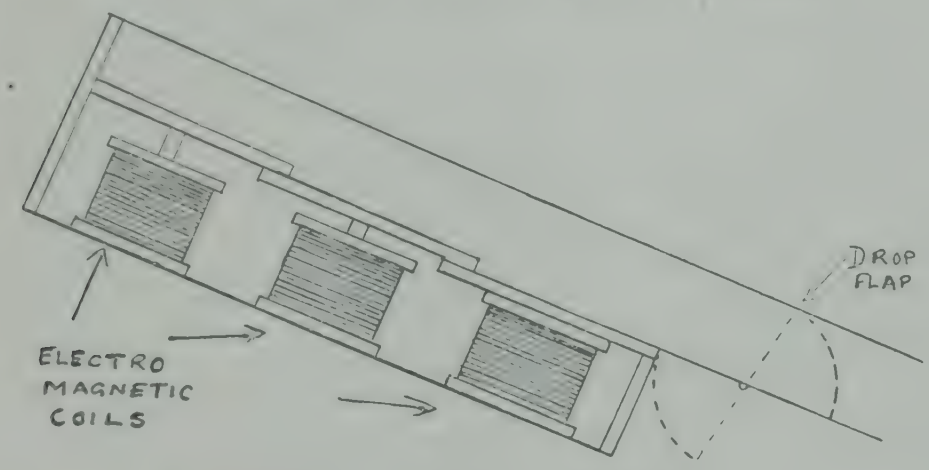


Fig. 7. Electro Magnet for extracting metal

PESTS IN OIL SEEDS

Sources of Infestation

The chief pests that concern the seed crusher are insects, i.e., beetles and moths and, like all organic materials, oil seeds are liable to attack by these pests. The primary effect of these attacks is to reduce the value and quality of seeds, particularly in cases of heavy infestation. Contamination may arise in a variety of ways.

In many cases, the insects live on the plants and get into the seeds before harvesting. Alternatively, a clean consignment of seed may become infested through storing in an infested warehouse before shipment. The dirty holds of local river craft, which are used to transport the seed to the coast, are also a source of infestation. Again, the cargo ship itself may harbour insects in its holds.

By whatever means contamination has been effected, and however small the degree of contamination, the ultimate damage and loss will depend to a large extent on whether the general conditions are suitable, or otherwise, for the rapid procreation of the pests.

In general, the best conditions for the breeding of most pests are :

The minimum degree of disturbance.
Warm, moist atmosphere.
Darkness and bad ventilation.
High moisture content of seed.
Seed which has been damaged, say, by water.

With these points in mind, it will be obvious, therefore, that the best means of reducing, or preventing infestation, is to attempt, as far as possible, to produce conditions which will be the exact reverse of those quoted above.

Since at this stage we are mainly concerned with the limitation or prevention of infestation, it would be advisable to review the sequence of production of the seed up to the time of arrival in this country.

Usually, the cultivator is alive to the danger of pests, and where he has reason to believe that infestation or attack by insects is liable, he carries out whatever measures are in his power. These preventive measures usually consist of frequent spraying with insecticides or, in some cases, picking out infested fruit or burning infested plants or seeds.

Assuming that a clean crop has been obtained, the grower then ensures that only clean, uncontaminated bags are used when the crop is being packed. The journey to the coast may be by either river craft or rail. It is important, therefore, that these means of transport are disinfected before loading commences.

At the coast, the crop may be stored in a warehouse which has previously been used to store other materials. In this case, infestation is liable if decontamination is not carried out frequently. If the crop has escaped the attention of pests so far, the ships' holds are the next risk, particularly if the previous cargo was infested and the necessary cleansing measures had not been effected.

From the points stated it will be evident that, sooner or later, there is a distinct possibility of attack and, therefore, the likelihood of pests in any particular parcel of seed is an ever present risk.

Our primary concern, however, is how to limit infestation or, alternatively, how to prevent it after the arrival of clean seed. Before dealing with this procedure, it would be advisable perhaps, to learn something of the more common types of insect found in cargoes of oil seeds; their habits and life cycle, if known, as this may assist in the best course to pursue.

Types of Pests

Types of pests fall into three main groups :

(1) Beetles.
(2) Moths.
(3) Mites.

The first group can be divided into two further groups :

(a) Weevils.
(b) Other beetles.

There are very many varieties in each of these groups, and it would not be advisable, nor would it be possible, to take more than a few of the more serious agents of destruction.

(a) Weevils differ from other beetles in their possession of a long snout, or proboscis. There are two types of weevil which closely resemble each other.

The first of these is the grain weevil, *Calandria Granaria*; the second, *Calandria Oryzæ*, the rice weevil. The life cycle and habits of both these types is similar, but the *C. Oryzæ* can

Fig. 8

Tribolium Confuseum (Actual Size 5/32″) | *Necrobia Rufipes* (Actual Size 5/16″) | *Calandria Oryzæ* (Actual Size 3/16″)

fly at certain times in the year. Whilst it is known as the rice weevil, it has been known to attack both linseed and cocoa beans. This weevil is also more common in the tropics and is, therefore, the more serious.

Weevils attack seeds by boring into them with their long snouts and depositing their eggs in the hole made. The larvæ, on hatching, usually remains inside the seed and eats away the centre. For this reason, they are not easily detected.

(b) The more serious of the beetle pests are undoubtedly those in the family *Tribolium*. They differ from the weevil in that they have no snout.

There are two kinds of this beetle, which is also known as the flour beetle :

(1) *Tribolium Castaneum.*
(2) *Tribolium Confuseum.*

Both these types are very similar in appearance and habits, the chief difference in appearance being in the shape of the antennæ, which, in the case of the *T. Confuseum,* is narrower at the end than that of the *T. Castaneum.* Both types may be found in copra, ground nut, etc. The larvæ of these beetles do not live inside the seed on which they feed. The female lives for at least a year, and lays one to two eggs a day; the time of development from egg to adult being about forty days. Both types are killed at temperatures of 125 to 130 degrees F.

Another pest of oil seed is the copra beetle, *Necrobia Rufipes,* sometimes known as the red legged ham beetle. This beetle has a polished, blue black appearance, and is much larger than the flour beetle. When examined under the microscope, it is seen to be covered with coarse, black hair. The chief materials attacked are copra and palm kernels. Several eggs, about 1 m.m. long, are laid in clusters, the larvæ being about 10 m.m. long. The females are known to live about fourteen months and lay about 2,100 eggs. The incubation period is four to five days, and the life cycle, from egg to adult, is from thirty to sixty days.

MOTHS.—There are many types of moth which inhabit cargoes of oil seeds, notably ground nuts. The female of most species may lay 148 eggs in a few days, the incubation period being seven to eight days. Eggs are laid in crevices or cracks in walls, bags, etc. The larvæ commences to feed and spins a loosely woven gallery in which it secretes itself. The life cycle of the moth is anything from six to eight weeks.

MITES.—These tiny creatures usually attack cargoes of seed which have already been badly damaged by other pests, particularly after prolonged storage.

Time and space do not permit a detailed history of all the pests named, but it can be assumed that under favourable conditions, the female of most of the species will lay as many as 200 or more eggs in from four days to several months. Some of the groups produce two to five generations per year. The warmer the atmosphere, the more numerous the generations. The life cycle of insects may range from thirty to sixty days.

Methods of Combatting or Limiting Infestation

In bad cases of infestation, fumigation is the only remedy if the material is to be stored. Many special preparations are in use as fumigants, notably, hydrocyanic acid, ethyl oxide, methyl bromide, etc. Fumigation, however, is a job for the expert only.

The more general measures of combatting all these pests are:

(1) Ventilation. This will assist in keeping store temperature at a minimum.

(2) Spacing. Piles of sacks containing seed should not be stowed against the warehouse walls. A passage, two to three feet wide is advisable between the pile and the wall. All separate consignments should be divided by similar passage way: this also assists ventilation.

(3) Cleanliness. Since infestation may be caused by a previous parcel in the warehouse, cleaning and white-washing of walls and regular brushing of floors should be carried out. Bags of sweepings and rubbish should be disposed of immediately, and not left lying about.

(4) Rotation. Where similar material is arriving in regular consignments, the oldest piles should be disposed of first, and not allowed to stand in the store for long periods.

When searching for traces of insects, the warmest and darkest places are the most likely habitations. Always examine the spaces between adjacent bags and the ears and stitching folds of bags.

One big advantage enjoyed by the seed crusher is the fact that all pests in oil seeds will be destroyed eventually in the cooking process prior to crushing, but this should not be used as an excuse for failing to carry out any possible method of preventing or limiting infestation.

CHAPTER IV.

STORAGE OF RAW MATERIALS

Oil seeds, in general, are seasonal crops and are shipped to the United Kingdom as soon as possible after harvesting. There are two main reasons for this: (1) deterioration, and (2) infestation. Both of these conditions are accelerated by storage in tropical countries.

As a result of this practice, the rate of arrival of the raw materials during a given period after the harvesting season can by far outstrip the crushing capacity of the mills.

At the same time, the demand for the products of the seed crushing mill are not essentially related to the seasonal supply of the raw materials. The demand for oil for soap making, margarine, etc., though liable to fluctuations, is a far more constant factor than the supply of the seeds used in the manufacture of these products.

In a previous chapter, it will be remembered that the harvest period for ground nuts was indicated as between, say, November and February, a period of approximately four months. So far as the seed crusher is concerned, however, it is desirable that these crops should be crushed over a period of twelve months, in order to even out the supply of the oil mill products.

The answer to the problem is storage.

Methods of Storing Raw Materials

The storage of the raw materials used by the seed crusher may be achieved by the use of two distinct methods, namely, in bags and in bulk.

BAG STORAGE.—Most cargoes of seeds arrive in this country in bags, the latter being unloaded by means of nets or slings. The bags may then be transported to inland sites or to warehouses near or in the dock area.

This type of storage has a distinct advantage in that bags can be stored almost anywhere, and special warehouses are not necessary. For instance, a warehouse previously used to house tobacco, hides or bales of cotton can, when emptied of these commodities, be restocked immediately with bags of ground nuts.

This feature gives greater flexibility to the seed crusher because it enables him to avail himself of storage facilities additional to his normal requirements.

A warehouse of the type referred to is sufficiently general in character to make a detailed description unnecessary; it should, of course, include hoisting or other elevating equipment.

In warehouse storage, the bags are stowed in piles on the different floors and, as mentioned in the chapter on pests, the bags should be stowed in such a fashion that each pile is surrounded by a passage way. Apart from giving easy access to any particular section of the floor, the leaving of passage ways enables maximum ventilation to obtain, thus reducing the risk of heating and discouraging insect pests.

Other important points that should be remembered in connexion with warehouse bag storage are that the height to which bags may be piled depends upon the weight per square foot of floor space which the floor can safely stand, maximum loads are required by law to be plainly indicated on each floor; clearance between the top of the pile and sprinkler heads, in case of fire; regular and neat stacking for easy checking.

BULK STORAGE.—Although the storage of raw materials in bags possesses certain advantages, bulk storage is considered the more efficient method.

For the purpose of storing oil seeds in bulk, use is made of large silos or converted warehouses, in which seeds are stored after removal from bags or direct from the ships' holds if in bulk.

Bulk storage silos are of special design, this depending upon the nature of the material to be stored. Therefore, the flexibility which is an advantage of bag storage is not possible to the same extent in silo storage. For instance, it would not be possible to switch over from oil seeds to bales of cotton or tobacco, merely to make use of storage space when this was not required for its original purpose.

Bulk storage of oil seeds tends to be confined to short term requirements, one reason being that material stored for excessive periods in large silos has a tendency to "sweat," due to the absence of ventilation. In other words, the crushing mill makes use of bulk storage for its more immediate requirements.

Of necessity, most crushing mills work twenty-four hours per day. As intake may be possible during daylight hours only, it is clear, therefore, that a twenty-four hour supply must be received and stored in eight hours.

For many reasons, the majority of crushing mills prefer a greater storage margin than twenty-four hours, and are usually equipped with silos to accommodate their particular requirements.

It is not intended, in this chapter, to deal with intake mechanism, and we will assume that the seed has arrived at the stage when the silo is about to be filled.

After weighing, the seed passes via an elevator into its appointed silo.

Silos may be constructed either of concrete or steel, and are usually square or rectangular in sections. The base of the silo varies somewhat in shape, depending upon the ease of flow of the seed to be stored. Silos which are required to store a considerable range of seed are constructed to enable the more difficult types, such as woolly cottonseed, to flow as evenly as possible. The more free flowing seeds, such as palm kernels and ground nuts, are thus catered for automatically.

Individual silo capacity may range from 50 to 300 tons, depending upon the requirements of the mill.

Many of the older types of silo consist of utilizing the floor

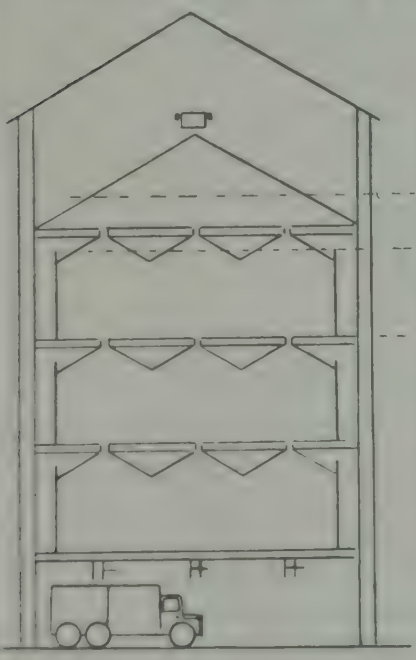


Fig. 9.

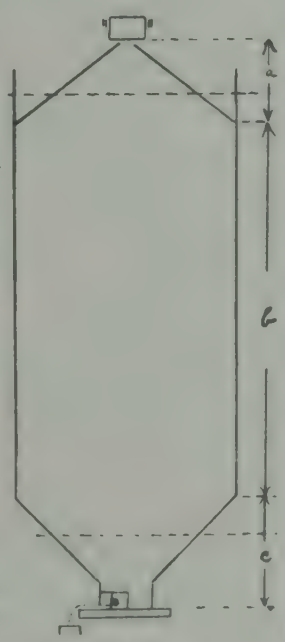


Fig. 10.

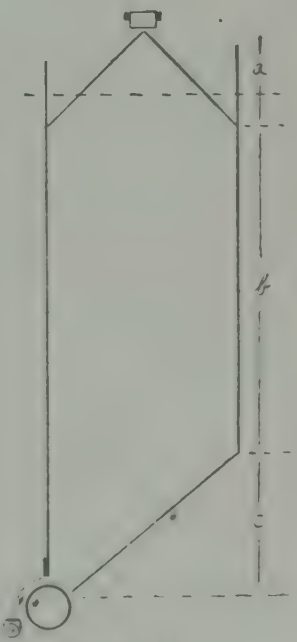


Fig. 11.

space of huge warehouses, the usual procedure being to cut holes one foot square in the floors (Fig. 9). This type of silo is usually fed by a bucket elevator which tips the material through feed hoppers above the top floor. A disadvantage of this type is that the silo does not empty or fill completely. After the silo has ceased to run, it will be found that considerable quantities of seed rest in the areas between the floor holes, pyramid fashion. Conversely, when the silo has been filled, it will be found that the seed forms a pyramid which converges towards the bucket elevator on the top floor, and towards the holes in the floor above. This characteristic is taken into account when calculating the capacity. In order completely to empty this type of silo, use is made of a plough attached to a wire hawser, by means of which the material is swept over the holes in the floors.

The later types of steel silo are specially constructed at the bottom in order that all of the seed will flow without assistance. The lower portion of this type of silo tapers off to form an inverted pyramid, or cone, the sides being a little steeper than the angle of repose of the seed. The angle of repose is that angle at which seed ceases to flow and is more or less constant in a given material.

It is always necessary to know the quantity of seed in the silo plant. Assuming the silo to be full, the cubic capacity, multiplied by the weight per square foot of the material in the silo, will indicate the total quantity in the silo.

Cubic capacity equals length × breadth × height.

Since the top portion of the seed will form a rough pyramid, the height taken for calculation purposes is one-third of the distance between the tip and the base of the pyramid (a) Fig. 10. To this is added the distance (b) and also one-third of the distance (c).

To take a specific case: A silo, with a section 15 ft. × 15 ft. measures (a) 9 ft., (b) 36 ft., and (c) 12 ft., conical base.

The cubic capacity of the silo is L × B × Ht.

$$15 \times 15 \times \left(\frac{9}{3} + 36 + \frac{12}{3}\right)$$

$$= 15 \times 15 \times 43$$

$$= 9{,}675 \text{ cubic feet.}$$

Material in silo is ground nuts at 40 lb. per cubic foot. How many tons of ground nuts will there be in this silo?

$$\therefore \frac{9{,}675 \times 40}{2{,}240}$$

$$= 172.76 \text{ tons.}$$

Fig. 11 shows a silo designed particularly for the storage of cottonseed. Woolly cottonseed will not flow without some inducement and accordingly, this silo slopes off in one direction only towards the feed roll.

The feed roll consists of a wooden roller running the full width of the silo and placed immediately below the outlet. The diameter of the roll is about 2 ft. 6 ins., and grooves are cut at intervals along the face. The cotton seeds are gripped in the grooves and persuaded to travel forward by the revolving movement of the roll.

In calculating the volume of this silo, the distance (c) should be divided by two; in other respects, the same method will apply as that indicated for calculating the volume of the silo shown in Fig. 10.

CHAPTER V.

COTTONSEED GINS AND DELINTERS

COTTON GIN.—This is a machine used to remove the lint, or floss, from cottonseed. The original gin was the primitive roller type used in India for the treatment of the Sea Island varieties of cottonseed, which varieties give up their lint fairly easily.

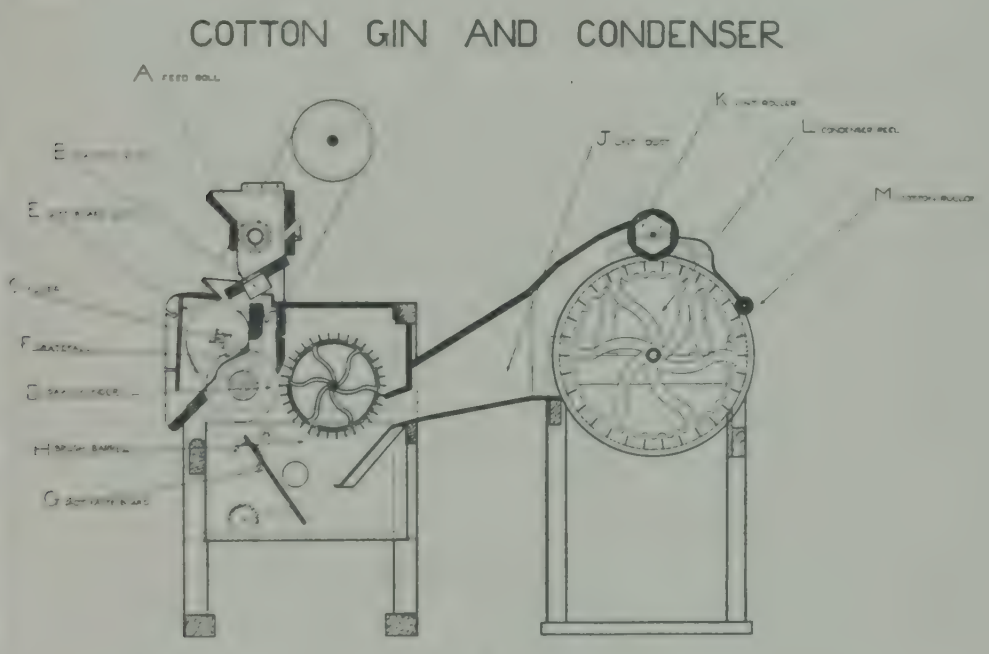


Fig. 12

The upland varieties of cottonseed present a very much greater problem. The outer long staple lint on these seeds is known as the floss. Prior to the invention of the saw gin in 1794 by Eli Whitney, the floss was removed by hand-picking. The hand-picking operation was a slow, tedious and costly business and imposed a severe restriction on the growth of the industry in America in the early days of cotton production.

In those days, the separation of the lint from the seed was carried out by the families of the field labourers after the

plucking was finished for the day; the average yield of separated cotton lint was about four pounds per household per week.

Although certain other machines had been invented, there is no doubt that it was Whitney's saw gin which revolutionized the cotton growing industry, production being increased by leaps and bounds thereafter.

The first saw gins were hand driven and contained but a few saws. The advent of steam power and, later of electricity, resulted in larger gins containing from sixty to eighty saws.

Seed cotton has a lint content of approximately 35 to 38 per cent., and the ginner removes about 33 per cent. by weight of the total seed.

The inner layer of tightly clinging short staple lint is known as the fuzz. This fuzz is not removed by the lint producer, and the seed is shipped with a lint content varying from three to twelve per cent. The seed crusher usually removes the fuzz from the seed before the oil removing process, and this may be accomplished in many different ways. Some of the seed contains a proportion of lint which is suitable for removal by means of a delinting machine or second cut gin.

A delinter is similar in design and principle to the first cut gin, but contains many more saws, fitted nearer to each other than is the case in the field gin.

Another type of delinter used by the seed crusher consists of a set of emery stone pads, revolving on a central shaft. In this machine, a set of fixed pads fit concentrically around the revolving pads, but with a variable space between. On being fed into the machine, the seed is scrubbed clean by the action of the pads before being passed out. The lint is carried away by a set of saws which obtrude through a combing into the scrubbing chamber.

The lint produced by this machine is poor in quality, but the resulting seed can be treated in the same manner as naked or *G. Barbadense* types.

SECOND CUT GIN OR DELINTER.—Since the cotton producers' gin is similar to the seed crushers' gin or delinter, we might study a typical second cut gin in a modern cottonseed oil mill.

The main working part of the gin is a set of circular saws $12\frac{1}{2}$ inches in diameter (D). These saws, of which there are 141, are fixed on a shaft with distance pieces between each saw to keep a fixed distance of half an inch between them. The saws, which obtrude through a combing, or gratefall, (F), have a speed of 620 r.p.m.

The combing has a bulged surface, set at an angle across the upper portion of the saws. Above this, a flyer, or elongated paddle (C), revolves in a chamber formed by the gratefall and the seed board (E) clamped to the side cast-iron cheeks.

At the back of the saws, in the housing, a circular set of

brushes (H) revolves against the saw teeth.

The seed is fed from a hopper mounted above the machine, via a feed roll (A) on to a magnet (B). The magnet removes any nails, bolts, nuts, etc., which may have got into the seed after the preliminary dressing. From the magnet, the seeds fall into the flyer chamber or breast and are whirled against the revolving saws. A lower adjustable combing, fitted to the seed board, keeps the seed in the flyer chamber while the saws tear the lint from the seed.

When the volume of the seed has been reduced by the removal of sufficient lint, the seed drops through the space between the fixed and movable combings, and on to the next process.

The brushes (H) bear against the saw teeth and carry the lint clear. The speed of the brush shaft is 1,110 r.p.m., and the diameter of the brush barrel is eighteen inches.

The high speed of the brush sets up an air current which sucks the lint through a narrow duct (J) and against a condenser (L).

A roller (K) presses the lint into a flat sheet, or bat. The lint is then wound round a roll (M) which can be removed and emptied, when full, into a baling hopper. In the case of a battery of gins, the lint is sucked via a fan to a main condenser.

A mote board (G) can be adjusted to produce a good quality lint, the husky lint then falls below into a screening hopper.

One gin will deal with two to three cwt. per hour, depending on the percentage of lint removed. The percentage of lint recovered is from 0.6 to 1.5, and the smaller the cut, the higher the quality of lint recovered.

A much deeper cut, resulting in a bigger yield of poorer lint, can be obtained by closing in the seed board at the front, by lifting the combing to close the seed exit aperture.

The life of the saws before resharpening is necessary, is about eighty to one hundred working hours.

When the saws require resharpening, the shaft on which they are fitted is removed from the gin and fitted into a machine known as a gummer. The gummer projects a series of small disc files against alternate saws. The gummer files describe a circular motion which cuts the saw tooth a little deeper. The saw shaft turns slowly, while the revolving gummer files move forward and away for each tooth. This process continues until all teeth have been recut.

The saw shaft is then removed from the gummer machine and fitted into a sharpening machine. The sharpening machine, or filer, projects a set of small triangular files, one at each alternate saw. The saws are suspended on strips of spring steel which enable a tension to be maintained while the file is in action.

The files describe a reciprocating motion which sharpens the teeth. The saw-shaft turns slowly while sharpening is in progress, and the spring adjustment enables the files to fall against each successive tooth. When a complete revolution has been turned by the saw-shaft, the machine stops automatically and the filing re-commences on the other side of the teeth.

When sharpening has been completed, the shaft is removed and can now be placed in the next delinter requiring saws.

NOTES ON OPERATION OF DELINTER.

The lint yield increases with saw cylinder speed, number of teeth on the saws, and tightness of the roll of seed in the flyer chamber. A corresponding increase in the horse power consumed takes place.

The saw speed of 620 r.p.m. gives about the maximum lint yield. To obtain the best quality lint, the speed of the saws should be reduced to about 450 r.p.m. The magnets above the float chamber should be cleared before shutting off the current; otherwise, iron or steel collected thereon will drop into the breast of the machine and cause damage.

The mote board should be adjusted by observation, to ensure that only broken hulls, and not pure lint, shall drop into the moting or screenings conveyor below.

The opposite fault consists of allowing the pieces of hull to be sucked with the lint to the condenser, and thence to the baling hopper. The nearest correct setting of the mote board can be obtained by trial and error.

If a heavy cut of lint is desired, the condenser should be speeded up to keep a constant thickness of the bat of lint, otherwise a check would be imposed upon the air flow caused by the brush.

CHAPTER VI.

MECHANICAL INTAKES

In the majority of cases, shipments of most types of oil seeds are made in bags rather than in bulk. The chief reason for this lies in the method of obtaining the material in the first place.

Loads of seeds are usually bagged on the plantations, and the bagged material is then either carried or carted to the nearest railway station or river craft. The bags are then transported to the port of shipment where they are stowed in warehouses or in the open to await shipment.

The cargo is loaded on to the ship by means of derricks, and on arrival in the United Kingdom, any of three separate methods of discharge may be adopted.

(1) Bags may be unloaded direct to quay for removal to inland sites.

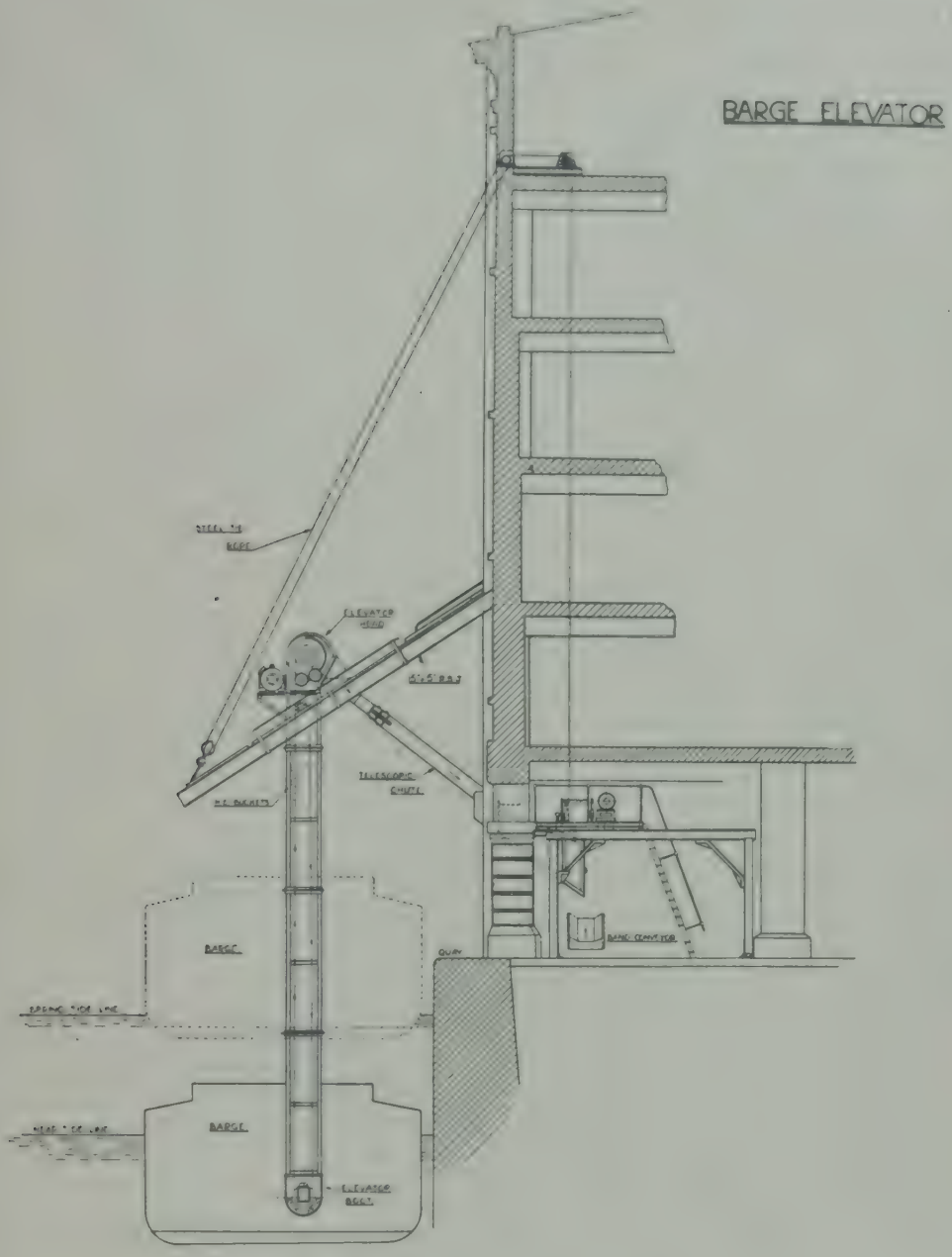


Fig. 13. Fixed Barge Elevator.

(2) Emptying of bags at quayside and discharge into bulk storage.

(3) Bags may be emptied into barges for subsequent bulk storage at a distant wharf.

In the first method, the bags, on reaching the quay, may be stored in tiers in the dock warehouse and removed later by means of tractors to the mill.

In the second case, the bags are opened and emptied from a platform on the dockside to a receiving band conveyor which conveys the seed via a weighing machine into silos for storage.

It is not always possible for the ship carrying the cargo to be berthed alongside the quay on which the bulk storage site

stands, and it is in such cases that the third method of discharge is adopted.

When it happens that the ship cannot be unloaded direct to storage, the ship is taken to a suitable berth, barges are brought alongside, and the bags, on being lifted from the holds, are opened and emptied via a chute into the barge. The barges are then taken to the bulk storage wharf and discharged by bucket elevator or pneumatic intake plant. The bucket elevator or pneumatic intake are also used, of course, in cases where the cargo has been shipped in bulk.

The Bucket Elevator

The fixed elevator to be described is particularly suitable for the discharge of barges into which seed has been loaded from bags.

The fixed, or wall elevator is used where the design of the quay does not allow room for the movable type of elevator. The fixed elevator jib is mounted on hinges on the warehouse wall at a point about thirty-one feet above the quay.

The construction of the jib is of strong steel girders, braced at intervals; the length of the jib is about thirty-three feet. The bucket section is slung at a point about two-thirds of the length of the jib from the warehouse wall end.

The buckets are carried by means of two chains which run over toothed wheels. The two wheels at the top are known as the head wheels, while those at the bottom are known as the boot wheels. The head wheels are much larger than the boot wheels, the reason for this being a better ejection of the material from the buckets.

Immediately below the head wheels on the ejection side, two carrier wheels are fitted. These carrier wheels direct the chains slightly inward on the downward travel, thus enabling the exit hopper to be fixed closer to the head.

The elevator boot wheels are as small as possible, in order that the boot of the elevator may be allowed to sink more easily into the mass of material.

The chains and buckets are encased in a sheet steel housing with guides for the chains at intervals. The steel housing encasing the chains and buckets terminates about three feet from the base of the boot, leaving the buckets free access to the seed. The two sides carrying the bearings of the boot pulleys are connected by a series of round section steel bars.

A tensioning device is fitted at the boot end which enables any slack in the chains to be taken up when necessary.

The jib is raised or lowered by means of a steel cable attached near the outer end and is wound on an electric winch.

Each bucket will hold about 25 lb. of seed, and the number of buckets on the elevator is 77. The speed of the elevator is 201 buckets per minute.

The spout from the ejection hopper is telescopic, in order to accommodate the continually changing position of the elevator. The exit end of the telescopic spout is near ground level. To facilitate weighing and distribution, the feed is carried on shallow, fast moving conveyors to an inside bucket elevator, over a weighing machine at two tons per tip, and thence to another band conveyor which will take the seed to any part of the warehouse.

By means of a simple calculation, it is possible to find the hourly capacity of a bucket elevator. Multiply the weight (in lb.) per bucket by the number of buckets (per minute), and then by sixty (minutes), dividing the total by 2,240 (lb. per ton).

Taking the figures already given, the capacity of the elevator described would be arrived at as follows:

$$\frac{25 \times 201 \times 60}{2{,}240}$$

$$= 134.6 \text{ tons per hour.}$$

The chief disadvantage of this type of elevator is that being a fixed jib, it has no lateral movement and, therefore, it cannot be moved to different sections of the barge when the section on which it has been working is cleared. Because of this, it is necessary to move the barge itself from time to time and, in addition, when the barge is nearly empty, a plough is used to concentrate the remaining material close to the elevator boot.

The plough consists of a heavy wooden plate measuring about three feet × three feet with a handle along the top. The plough is pulled along by means of a cable connected to a hydraulic installation located inside the warehouse and is guided by an operator in the barge hold.

It has already been stated that this elevator, being fixed on the warehouse, while being capable of movement in a vertical direction, cannot be moved laterally. For this reason, and the fact that the seed should completely envelop the boot, this is not the best type for use with cargo ships.

A cargo ship cannot be moved with the same ease as a barge, nor does the average berth admit of much movement by a fair size ship. It follows, therefore, that the best type of bucket elevator for unloading ships is the travelling type.

The Travelling Type Elevator

The travelling type elevator is mounted on a counter-weighted jib which pivots at a point near to the counter-weighted end. The whole is carried by a tower built of steel girders which runs on rails on the quayside. This elevator can move to various parts of the first hold, retract, and travel on the rails until opposite the second hold, where the emptying is carried out in the same manner as for the first hold.

The power units for this type consist of two electric motors,

one to drive the bucket system and move the jib, while the other provides the propulsion which moves the elevator along the quayside.

It was stated in the chapter describing a typical wall type elevator that the buckets were carried on two chains. This, of course, is not always the case, as in some types, the buckets may be bolted to a strong, wide belt of canvas and rubber.

Fig. 13 shows the elevator operating when the full tide is at its lowest level, whilst the dotted outline of the barge indicates the highest full tide. Probably, it is scarcely necessary to explain that docks are always at the level of the full tide, the water level being maintained by closing the gates before the tide commences to recede.

PNEUMATIC INTAKE PLANT

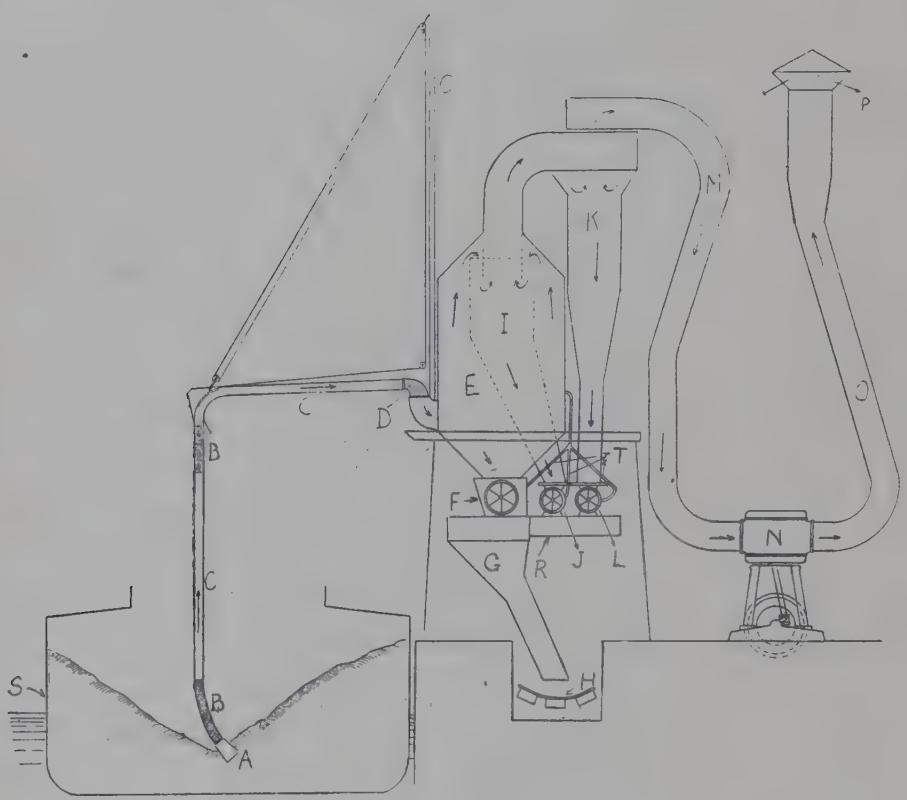


Fig. 14. PNEUMATIC INTAKE PLANT

(a) Nozzle taking in air and seed. (b) Flexible pipe reaching all parts of the hold. (c) Intake feed pipe to Receiver. (d) Universal joint to facilitate maximum range of movement. (e) Receiver where seed and air separate. (f) Air seal, feed roll. (g) Discharge hopper for seed. (h) Band conveyor taking seed to weigher and store. (i) Cyclone dust collector separating dust from air. (j) Air seal, feed roll for dust from inner cyclone. (k) Auxiliary dust collector for further dust removal. (l) Air seal feed roll from auxiliary cyclone. (m) Air pipe to exhauster pump. (n) Exhauster pump. (o) Air escape pipe. (p) Exhaust air to atmosphere. (q) Device for projecting and moving air and feed pipe. (r) Worm connecting discharge feed from air seal rolls. (s) Barge.

The type of installation best suited to the handling of large quantities of bulk seeds and nuts is the pneumatic intake plant.

Whilst the principle and general design of this type of intake plant is similar in all cases, the size and construction of the plant varies according to the needs of the mill and the type of ship likely to be discharged.

Accordingly, the large ports are usually equipped with pneumatic plants capable of discharging ships carrying cargoes of 5,000 to 8,000 tons, the rate of discharge being sometimes as high as 400 tons of seed per hour. The inland mill receiving cargoes by barge would not, of course, need a plant of such high capacity.

Fig. 14 shows the approximate layout of a port installation in process of discharging a river barge. The main item in the installation is the exhauster pump, by means of which air is sucked from the receiver (E), the exhausted air being replaced at the nozzle (A).

The nozzle is specially constructed, in order to ensure that air always has free access to the pipe inlet, even when the nozzle is buried in the bulk of seed. The section of one type of nozzle (Fig. 15) shows an annular sheath of metal surrounding the inlet pipe. By this means, air flows downwards from the upper opening, while the lower lip of the sheath keeps the inlet pipe from actual contact with the seed. The pipe, being of small diameter, usually about four to five inches, induces the air, plus the seed, to travel at a very high velocity. The vacuum induced at the inlet is about 10 ins. mercury gauge. The

Fig. 15. Section Diagram of Nozzle

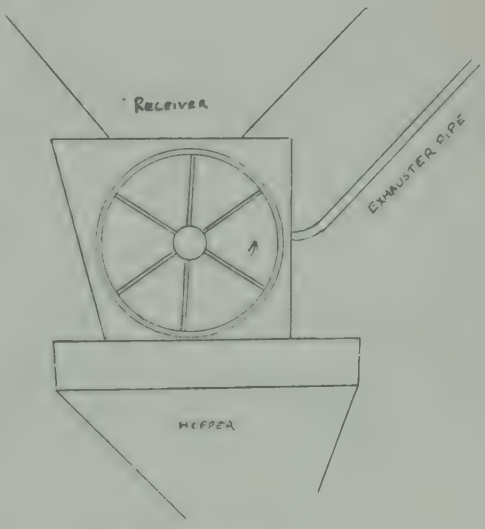


Fig. 16. Feed Roll

flexible construction of the pipe sections (B) enables the nozzle to reach all parts of the holds of the ship.

The air and seed flow into the large receiver (E) past a universal joint (D) which is shown clothed with weather proofing fabric. The universal joint enables the projected pipe to be moved in almost any direction.

On entering the large receiver from the narrow pipe, there is a considerable drop in the air velocity. This drop in the velocity causes the seed to fall to the bottom of the receiver, where it is passed out by means of the air seal feed roll (F). It will be understood that the pressure inside the receiver is considerably below that of the atmosphere, and, therefore, the feed roll must eject the seed without allowing air to leak in. The illustration of the feed roll shows how this is arranged (Fig. 16).

The feed roll consists of six or eight V-shaped chambers set radially from the centre; as each chamber comes opposite the open end of the receiver bottom, it is filled with seed which is then carried downwards and ejected into the hopper (G). As each chamber reaches the point opposite the exhauster pipe linked with the receiver, air is sucked out before the chamber is filled with seed. This prevents a loss of vacuum due to air passing from the feed roll to the receiver.

It is now necessary to refer back to the point where the air and seed entered the receiver. The air rises towards the point where the suction is being applied, and in order to escape from the receiver, it has to drop downwards past the extension of the pipe leading out from the inner cyclone (I). Here, a good deal of the dust from the seed continues to fall to the base of the cyclone and is ejected by the air seal feed roll (J).

The air, on leaving the inner cyclone, passes on to the auxiliary cyclone (K), where the remainder of the dust falls and is removed at the feed roll (L). By this time, the air is fairly clean and free from dust, and can pass via the pipe (M), through the pump (N), and out to the atmosphere via the exit pipe (O).

Dust from the feed rolls (J) and (L) is conveyed by a worm (R) into the hopper (G) with the main feed, on to a band conveyor (H) to a weighing machine, and thence to store silo.

Regarding this latter practice, a question that may possibly be asked is: "Why remove the dust and then put it back?" The answer is that the dust has to be removed before the air passes through the pump; otherwise, its presence would injure the working parts of the pump. At the same time, dust often consists of fine portions of sound seed, the weight of which must be accounted for accordingly. Therefore, it is returned to the consignment for use with the main bulk of the seed. In some cases, the dust removed is kept separate from the main feed and disposed of independently.

Intake plant of the type described may be built on the dock

side on a permanent base or may be carried on rails. If on a fixed base, the receiver and cyclones are usually outside in the open, while the pump and scale are installed in the dock shed. Alternatively, the elevator may be erected on a barge for moving from dock to dock.

In the case of the barge and rail elevator, the complete unit is carried on the superstructure, the only connexion with the shed being the telescopic pipe by means of which the seed is passed to the conveyor on the dock side, and wires carrying the current to the driving motors.

CHAPTER VII.

DECORTICATION—COTTONSEED

SIMPLIFIED SEPARATION.—The process of decortication is the removal of the husk or outer shell of the seed.

An examination of the analysis of a typical sample of ginned cottonseed (upland type) will show that the removal of the greater portion of the outer shell results in a considerable increase in the oil and albuminoid value in the finished meats and a lowering of the fibre content. These meats will produce a cake of far greater value than that obtained from undecorticated cottonseed.

The decorticator should be regarded as a plant, or series of machines, rather than as a single machine. The complete process consists of two separate functions.

(1) Hulling, cracking the husk.
(2) Separation, removal of loose husk.

Methods of decortication vary considerably with different types of seeds processed, though the principle is similar for all. This chapter will deal with a specific consignment of ginned cottonseed, i.e., woolly cottonseed which has been ginned by the oil miller in addition to original ginning.

The Huller

There are, of course, many types of huller, one of which, known as the Perfection Huller, is here described.

A cast iron rotating barrel, four feet long, is mounted in a specially built housing. The barrel has fourteen or sixteen knives recessed at even spaces round the circumference and running the length of the barrel. The space between the knives is a plain, flat surface, so that instead of the barrel being exactly circular, it is, in reality, a sixteen-sided figure.

The knives, however, are set true, and when the barrel rotates, the knives describe a true circle. The opposing knives are set in a concave casting mounted on the front of the huller.

and these knives are stationary. The gap between the rotating and stationary knives can be increased or decreased by turning a cam on the front centre of the concave.

The concave is slung from a 1½ inch shaft mounted on the main carcase, and held in exact position by adjuster bolts fitted

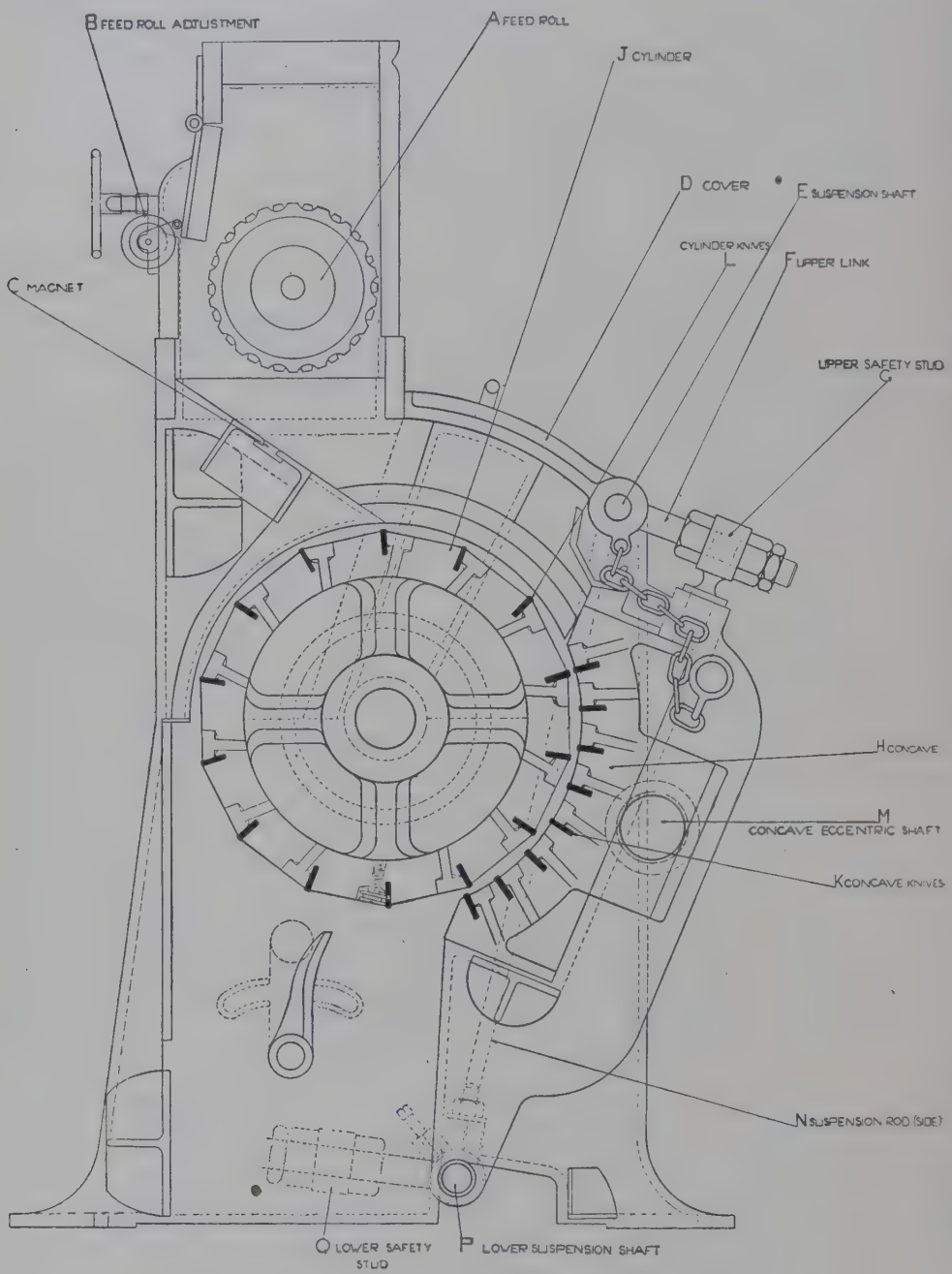


Fig. 17. Huller

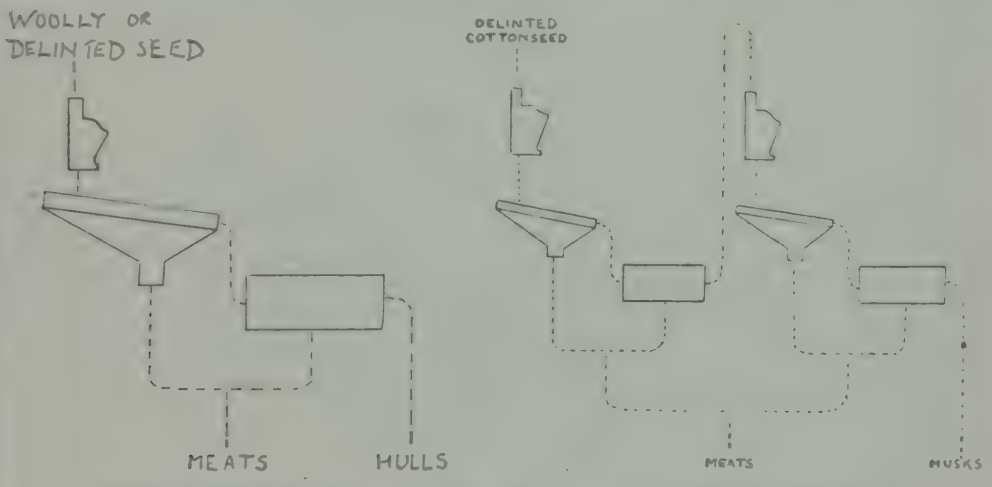
between the sling mechanism and the main carcase at the bottom, and between the 1½ inch top shaft and the top of the concave.

This method of mounting enables independent adjustment of the upper and lower knives. The gap when the huller concave is set properly varies with the type of seed used. The

setting for, say, East African seed of normal size and quality is about one-eighth inch top knife and one-tenth inch bottom knife. The intermediate knives will, of course, have clearances which progressively diminish from one-eighth inch to one-tenth inch. Between the adjuster bolt and the carcase at the bottom, and also between those from the sling shaft and the concave at the top, cast iron shear pins are fitted.

In the event of some foreign body getting into the seed feed, the machine could be badly damaged, but the provision of shear pins minimizes this possibility to some extent. When a severe impact occurs, the shear pins are broken and the concave falls forward. A stout chain is fitted between the sling shaft and concave top, and if the top shear pins go, the weight of the concave is taken by these chains.

Between the feed roll and the barrel a magnet is fitted in order to prevent stray metal from passing into the machine. The speed of the barrel is 960 to 1,000 r.p.m. The volume of feed can be varied by an adjustable hinged board in front of the feed roll. Feed is four tons per hour.



Single Hulling Flow Fig. 18 Double Hulling Flow

Single Hulling

Husk containing five per cent. or more lint can usually be separated by screening. The hulled seed is passed to a flat reciprocating screen. The screen is fitted with three-eighths inch or five-sixteenths inch sieving, or a combination of both. This again will depend upon the size of the seed. The husk will travel over the end of the screen and the meats, plus some of the husk, will pass through the screen.

At this stage, the separated husk still contains a small amount of fine meat which adheres to the lint. This is removed by passing the husk through a one-eighth inch reel. The searching action of the reel causes the fine meal or powdery meats to be beaten out and passes through the one-eighth inch sieving. The fine meats then join the main feed and proceed to the crushing

section for treatment. The separated husk is passed to a fine grinding plant, which enables the lint and husk bran to be separated by careful screening. The lint is baled and sold to the paper manufacturers, while the fine husk bran is used by the compound cake producer.

Double Hulling

This method is used in cases where the size of seed varies a good deal. When the seed sizes vary, it will be obvious that a given setting of knife clearances will not be correct for all sizes. If the machine is set up closely to cut small seeds, the larger seeds will be severely damaged. To offset this, double hulling is carried out in the following manner :

In the first hulling, the huller is set to cut about 70 per cent. of the seed, and the whole mass passed over the screen separator and fine meal reel. The husk containing the remaining 30 per cent. unhulled seed is fed to a second huller which has been set up to crack the smaller seed.

This time, all the remaining seeds are effectively cracked, and the dressing process repeated as in the first operation. The meat and fine meal join those of the first operation, while the husk is treated as in the single hulling process.

Check Test on Decortication Plant

We have now dealt with the theoretical determination of the amount of husk removed according to available analyses. The next step is to check the performance of the plant. To do this, the plant operator arranges to draw off the husk and meat feeds simultaneously for a period of, say, thirty minutes to two hours. Both products are carefully weighed, and the percentage decortication calculated from the amounts obtained.

OPERATOR'S TEST SHEET COMPLETED.

Period of test : One hour.

Meats produced :

31 bags @ 168 lb. nett	5,208 lb.
1 bag @ 116 lb. nett	116 lb.
Total	5,324 lb.

Husk produced :

58 bags @ 56 lb. nett	3,248 lb.
1 bag @ 15 lb. nett	15 lb.
Total	3,263 lb.

Plant throughput :

Husk	3,263 lb.
Meats	5,324 lb.
Total	8,587 lb.

Decortication :

$$\frac{3{,}263}{8{,}587} \times 100 = 38.1 \text{ per cent.}$$

Calculate Albuminoid (Protein) Value of Decorticated Cotton Cake

GIVEN ANALYSIS OF SEED AND TEST DETAILS ON PLANT.

	Oil	Albs.	Moisture	Fibre
Husk	1.0	4.0	10.0	38.0
Meats	31.0	36.0	7.0	2.5

Whole seed = 44 per cent. husk
56 per cent. meats

It may be that the laboratory analysis of the cake is not available and the operator is anxious to know, in advance, the albuminoid value expected.

METHOD.

The operator knows from experience that he can expect, say, 6 per cent. oil in cake. According to test figures, husk left in meats = 44 − 38 = 6 per cent.

∴ Oil in processed meats :

$$\begin{array}{rr} 56 \times 31 = & 1{,}736 \\ 6 \times 1 = & 6 \\ \hline 62 & 1{,}742 = 28.1 \text{ per cent. oil} \end{array}$$

Albuminoids in processed meats :

$$\begin{array}{rr} 6 \times 4 = & 24 \\ 56 \times 36 = & 2.016 \\ \hline 62 & 2{,}040 = 32.9 \text{ per cent. Albs.} \end{array}$$

Remove oil by expression : First remove total oil theoretically, this will result in the concentration of the albuminoid :

$$\frac{32.9 \times 100}{100 - 28.1}$$

Allow for 6 per cent. actually remaining in cake :

$$\frac{32.9 \times 100}{100 - 28.1} \times \frac{100 - 6}{100}$$

$$= \frac{32.9 \times 94}{71.9}$$

= 43.0 per cent. Albs. in finished cake.

CHAPTER VIII.

DECORTICATION—IMPROVED SEPARATION

The previous chapter on decortication dealt with details of the construction and function of the hulling machine, and with a simplified form of hull separator. There are, however, certain defects and limitations in the type of separator described.

When separation is carried out by screening only, unhulled seed and hulls must, of necessity, be passed together through a second hulling process. The tendency, therefore, is for oil from the second meats to be absorbed by linty hulls which have already been separated from their meat This results in an unnecessary loss of oil.

Screening alone will not give total removal of hull fibre or lint, the shorter staples succeeding in dropping through the screen and passing on with the meats. The presence of the fine fibre in the meats can in no way add to the value of the resultant cake, and it is desirable always that the purest product possible be obtained.

To correct the faults stated above, some sort of auxiliary separator is desirable. A combination of screening and aspira-

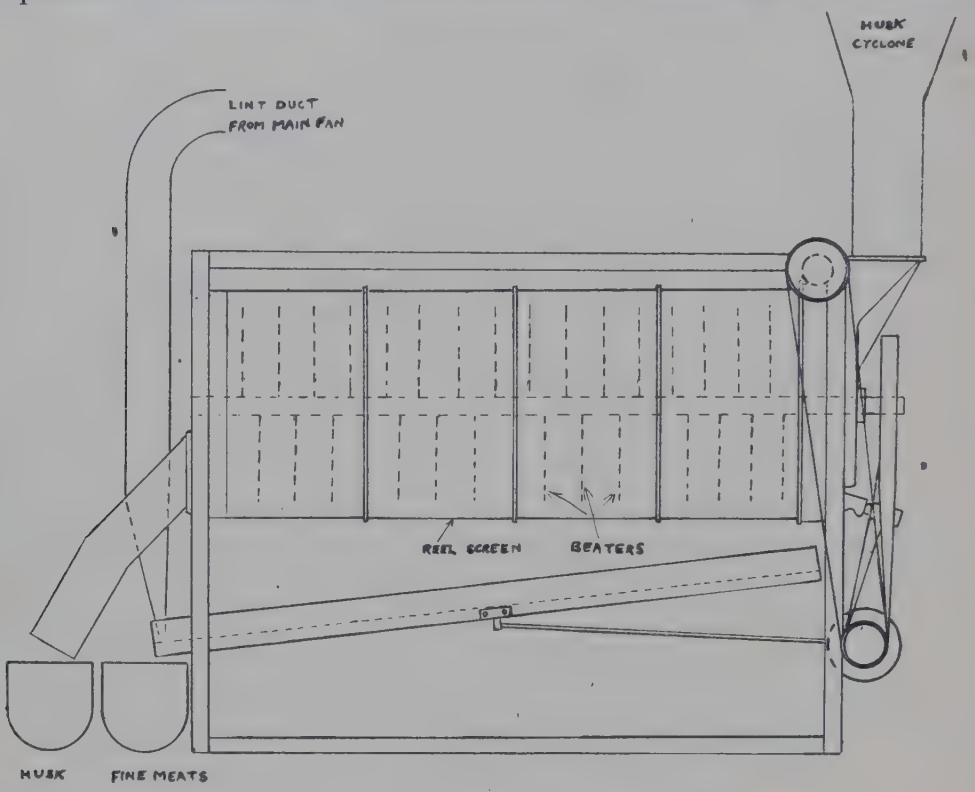


Fig. 19. Huller Beater

tion plant has been designed which corrects the weaknesses in the simple form of separator. This combination also has the effect of greatly reducing the travelling distance involved, and allows a convenient concentration of equipment.

Method of Separation—Description of Plant

The huller requires no further description, as the same type is used as was described in Chapter VII. The disc type of huller is generally fitted with this type of machine, though the huller already described may be used. Details of disc-huller will be described later. The huller is mounted over the front end of a strong steel frame and carried by the frame, by means of hangars are two separator screens of special design. The huller deposits at the head of the top screen a mixture of hulled and whole seed, preferably about 70 to 80 per cent. hulled seed and 20 to 30 per cent. unhulled seed. The screen is operated by an eccentric drive with $1\frac{1}{2}$ inch stroke and $\frac{3}{4}$ inch throw.

The free meats drop through the screen, the size of which must, of course, depend upon the size of the seed being processed.

The uncut seed and hulls travel to the lower part of the screen and over a low ramp which tends to slow up the speed of travel at this point. Immediately over this point is fitted the main part of the aspiration system.

The aspirator consists of a fan fitted with twin inlets for air. The air inlets project downwards to within an inch or so of the screen ramp. The upward pull of the intake air lifts the hulls, which are relatively light, and carries them via the fan to a cyclone above.

At this point, it is necessary to go back to the whole seed which, being too heavy to be carried up with the husk, carries on its forward journey and drops into a trough at the end of the screen. An inclined conveyor carries the seed up to the worm feeding fresh seed to the huller where this time the returned seed is hulled with the fresh seed.

As stated earlier, the meats from the hulled seed drop through the top screen to the lower screen. Most of the separation takes place in the first section, and under this section, on the lower shaker, a blank or plate is fitted. The effect of the blank is to cause any free lint which has inevitably dropped through the top screen with the meats to roll into tight little curls which ride easily over the meats.

After the blank, a fine mesh screen receives the meats and small particles pass through to the lower chamber of the shaker. Approaching the end of the shaker, above the screen, is a layer of larger meats, and above them a layer of light wavelets of lint.

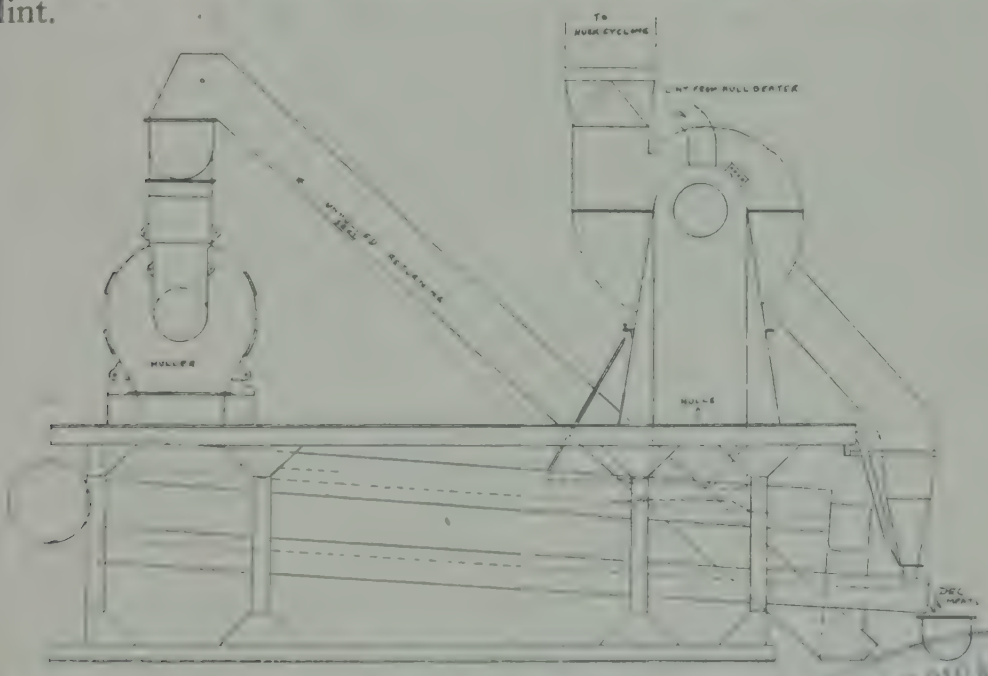


Fig. 20. Huller and Aspirator Equipment

Immediately before the end of the shaker, an aspirator duct linked with the air intake chamber is met. The aspirator lifts the light lint upward and carries it, with the hulls, to the cyclone, while the meats pass into a worm, as also do the small meats or fines from the lower chamber of the shaker.

It is conceivable at this point that the reader may ask: "Why separate the fine meats and then add them back at the end of the shaker?"

If the fine meats were not separated and passed into the lower chamber, there is a risk that much of these fines would be carried upwards with the lint or fibre.

The meats have now been separated effectively from the hulls and the hulls have been passed into the cyclone above. The cyclone allows the air stream to separate from the hulls and pass out through the top thimble while the hulls drop downwards into a hull beater. The hull beater consists of two reels driven by a worm and gear.

A central shaft running through each revolving reel is fitted with beaters which remove any adhering portion of fine husk or meat which have evaded the main separation devices. The fines from the reels drop to a shaker below the reels fitted with a blank. The action of this blank is similar to that of the blank on the lower shaker of the first fine meat separator. Any free lint is rolled by the reciprocating movement of the shaker and aspirated at the end by a similar attachment to the fan air intake as that earlier described.

The size of screens used on the shakers can be changed at short notice, and it is usual to carry a range of spares from $\frac{1}{8}$ inch to $\frac{1}{2}$ inch in order that most types of seed requiring decortication can be accommodated.

All aspiration points carry adjustment devices, as variations in the type and quality of seed call for differing strengths of air blast.

The plant described is, of course, primarily designed for cottonseed, but by means of certain adjustments, other seeds such as ground nuts, sunflower and soya beans can be treated.

The increased efficiency of separation results in a higher concentration of the albuminous and oil bearing portion of the seed.

DECORTICATION—GROUND NUTS

Mechanical plants of the type already described are capable of treating many types of seeds. In addition to cottonseed, ground nuts, sunflower, kurdi and kapoc are usually decorticated.

Ground nuts may be partly or fully decorticated, and are often treated in the country of origin. In the country of origin the nuts are often decorticated by hand, in which case, total

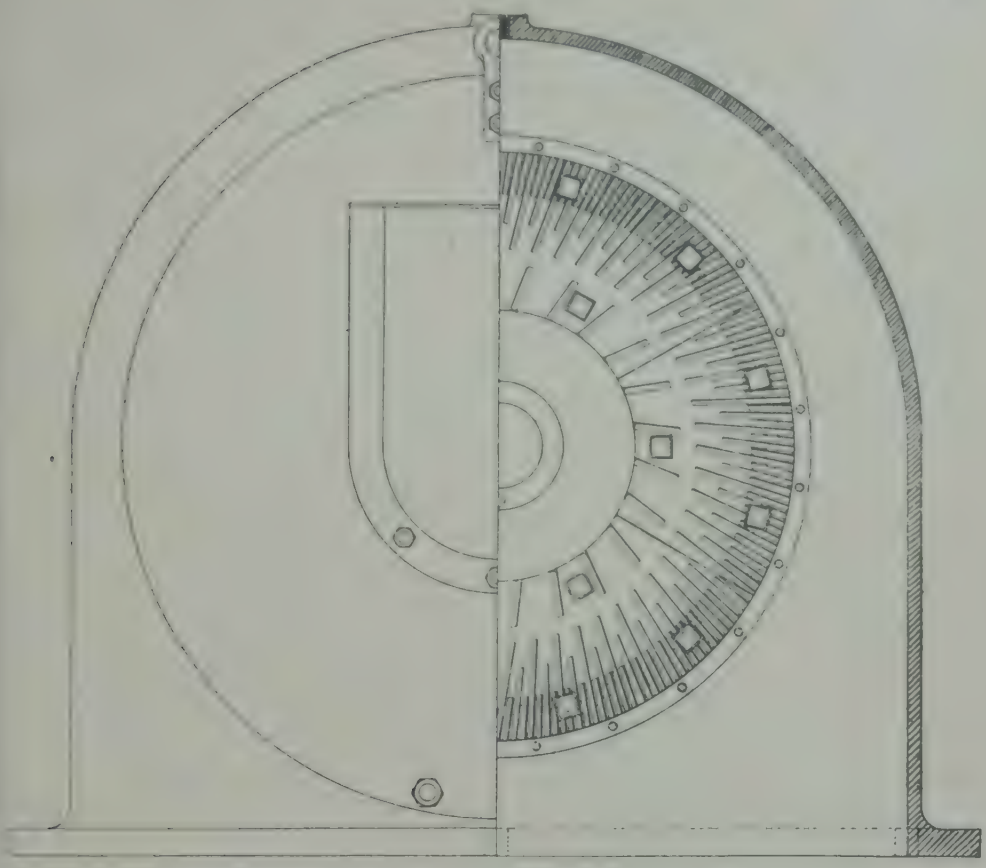


Fig. 21 Disc Huller—Side View

decortication is obtained. Fully decorticated nuts yield the maximum albuminoid value in the residual cake, while partly decorticated nuts will produce an albuminoid value proportional to the amount of husk removed.

Analysis of Ground Nuts

It must be remembered that the following analysis cannot be taken as constant for all ground nuts, and that each variety has values peculiar to its own group, with minor variations even within that group.

Accordingly, when practical application is carried out, it is advisable to obtain as complete an analysis as possible of the specific parcel of seed. It is assumed, therefore, that this has been done and results obtained are as follows :

	Kernels.	Shell.
Oil	48%	1%
Albuminoids	28%	4%
Moisture	6%	10%
Fibre	2%	65%

Amount of shell on whole seed 26%

The aspiration plant has obtained almost complete decortication; say, therefore, one per cent. of husk has been left in with

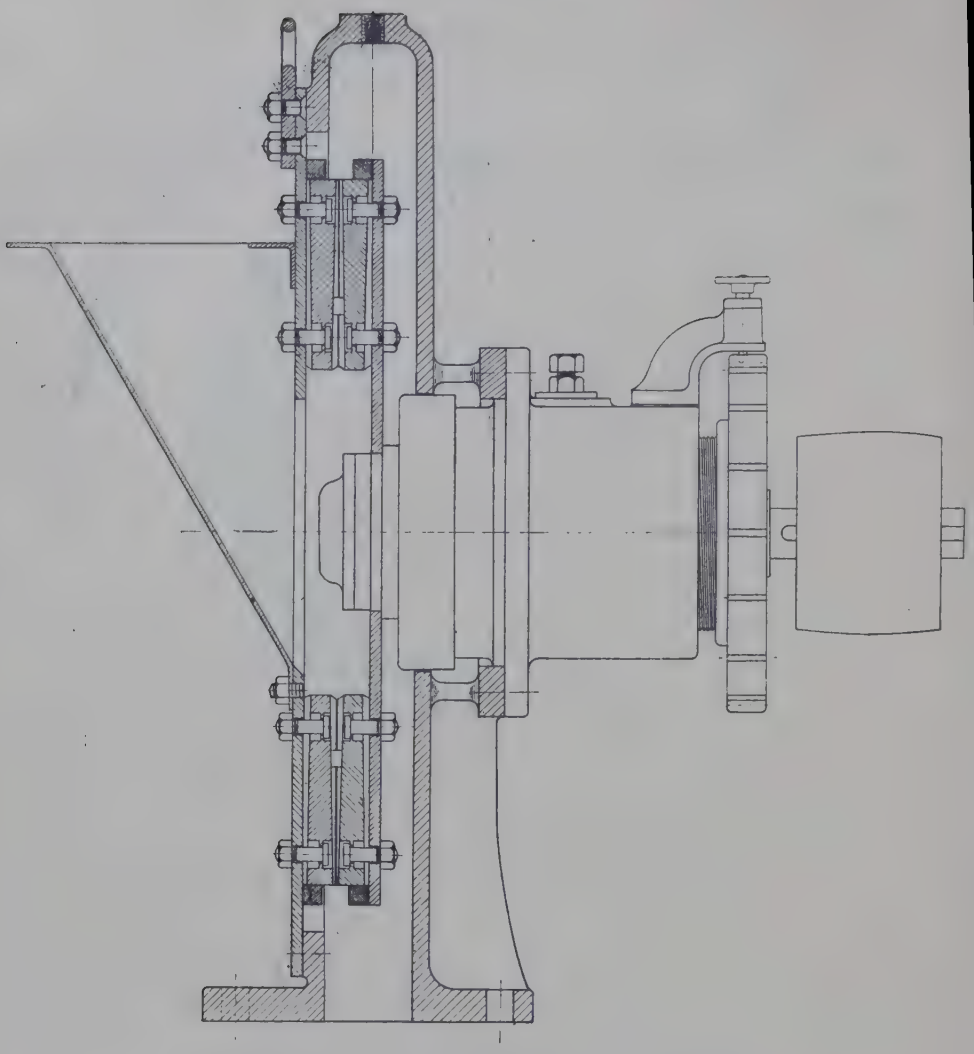


Fig. 22. Disc Huller—End View of Discs

the kernel. The analysis of the decorticated meat must first be calculated in terms of oil, albuminoids and fibre.

Oil in decorticated nuts :

Husk	1 part	@ 1%	=	1
Meat	74 parts	@ 48%	=	3,552
	75 parts			3,553

$$\frac{3,553}{75} = 47.37\% \text{ oil}$$

Albuminoids :

Husk	1 part	@ 4%	=	4
Meat	74 parts	@ 28%	=	2,072
	75 parts			2,076

$$\frac{2,076}{75} = 27.68\% \text{ albs.}$$

Fibre :

Husk	1 part	@ 65%	=	65
Meat	74 parts	@ 2%	=	148
	75 parts			213

$$\frac{213}{75} = 2.84\% \text{ fibre}$$

Remove most of the oil in press room, leaving 7 per cent. only in cake.

Value of resultant cake :

Albuminoids in cake @ 7% oil :

$$\frac{27.68 \times 93}{52.63} = 48.92\% \text{ albs.}$$

Fibre in cake :

$$\frac{2.84 \times 93}{52.63} = 5\% \text{ fibre}$$

In the case of the plant equipped with screens only, a much lower decortication is obtained even when a fairly high figure can be achieved, this is not in all cases desirable. To obtain a lower decortication, the screen sizes should be increased, resulting in the passing of a larger amount of husk with the meats.

It will be remembered also that the hulling process inevitably produces a percentage of fine meal which is a mixture of small particles of both husk and meat. It is difficult to separate the husk from this fine meal, and accordingly, the mixture is passed with the pure meats for processing in the oil mill. Moreover, the seed crusher may sometimes prefer that a percentage of husk be left in the meats, as the husk has a binding effect upon the mass and makes for easier working in the press room.

Partly Decorticated Nuts

The decortication obtained in this case will depend upon the requirements of the finished cake, and it will be assumed that 16 per cent. of the total weight of seed has been removed in the form of husk. This means that the balance of the husk, i.e., 10 per cent. of the total, remains with the meats.

The value of the decorticated meats in oil and albuminoid content is as follows :

Oil :

Husk	10 parts	@ 1%	=	10
Meat	74 parts	@ 48%	=	3,552
	84 parts			3,562

$$\frac{3,562}{84} = 42.4\% \text{ oil}$$

Albuminoids:

Husk	10 parts	@ 4%	= 40
Meat	74 parts	@ 28%	= 2,072
	84 parts		2,112

$$\frac{2,112}{84} = 25.14\% \text{ albs.}$$

After oil has been removed, the cake still retains 6 per cent. oil.

The albuminoid value of finished cake is, therefore:

$$\frac{24.8 \times 94}{57.6} = 40.6\%$$

Fibre:

10 parts	@ 65%	=	650
74 parts	@ 2%	=	148
84 parts			798

$$\frac{798}{84} = 9.5\% \text{ fibre in decorticated meats}$$

Fibre in finished cake:

$$\frac{9.5 \times 93}{57.6} = 15.3\%$$

Disc Hulling Machine

The "perfection" type of huller has been described in Chapter VII.

The disc type of huller is also suitable for ground nuts and is very different in design. The general description somewhat resembles a grinder.

A cast-iron housing encloses a pair of disc shaped cutting faces, one of which rotates at 500 to 800 r.p.m. The other disc is stationary and is mounted on the door panel of the casing. A hopper leading into the centre of the door feeds the nuts into the machine. The knives on the cutting faces are moulded with the casting and are about $\frac{3}{8}$ inch deep at the inner circle of the annulars, diminishing to $\frac{1}{4}$ inch at the outer circle.

The faces are built with six separate sections of chilled iron which are bolted to a main plate. The clearance between the fixed and movable disc can be varied by turning a large wheel which is part of the casting carrying the driving shaft, to which the rotating disc is secured. In this way, various degrees of hulling can be obtained.

CHAPTER IX.

SEQUENCE OF PROCESSING—LINSEED

All types of oil seed require suitable pre-treatment before the actual process of oil removal can be carried out.

Though in a broad sense, this pre-treatment follows the same general lines, nevertheless each type of seed requires special treatment to suit its own characteristics. The specific treatment is largely a matter of experience, but the analysis of the seed, together with observations of its physical characteristics, will assist in indicating the general line of procedure.

For our present purpose, we will assume that a cargo of linseed has arrived and been sampled. A representative sample has been sent to the laboratory, who issue a report on its analysis. A sample has also been examined by the responsible personnel of the mill, and the presence of rape and sand noted.

There may also be good reason to expect to find castor seed and stones in the cargo.

It can now be assumed that all possible advance information has been obtained, and the plant has been arranged in the processing order here described:

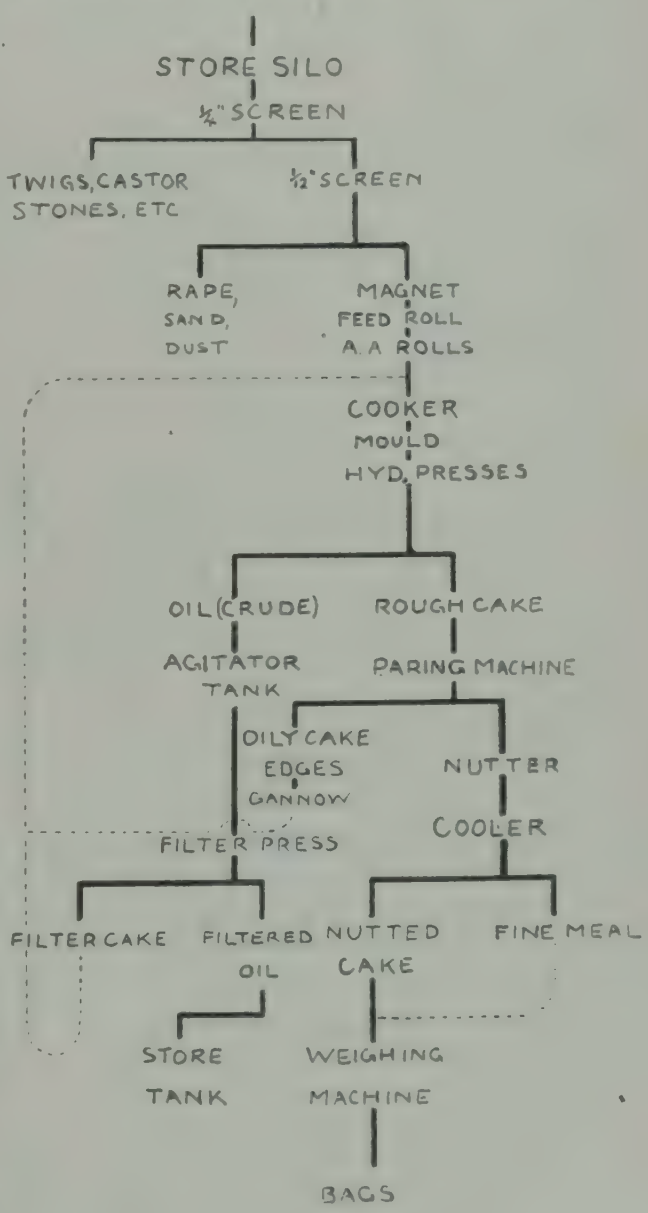


Fig. 23

STORAGE.

The seed has been carried by bulk wagon from the dockside receiving silo and placed into the mill silo.

DRESSING.

From the silo, the seed passes over a $\frac{1}{4}$ inch screen. Thi screen will pass the linseed, plus sand and rape, but will remov any large stones and castor seed. The seed then passes over one-twelfth inch sieve where the rape seed and sand pas through, whilst the pure linseed passes over the end of the scree to a cascade magnet for the removal of small slivers of stee and nails.

ANGLO-AMERICAN ROLLING.

The pure linseed now passes to a feed roll above a set o Anglo-American rolls. The feed roll assures a uniform depti of feed across the full width of the rolls. The A.A. rolls are o the five roll type, and will thoroughly break down the cellula construction of the seed.

COOKING.

The rolled seed is now ready for the cooker, which may be the two, three, or five chamber type. The application of jacket steam, as well as of "live" steam, brings the meal to a temperature of, say, 180 degrees F. This has the effect of further softening the seed meal and reducing the viscosity of the oil.

MOULDING THE CAKES.

The meal now passes into a mould or strickling box by means of which the mould chamber is evenly charged with the amount of meal necessary to make a cake. A piece of press bagging has, of course, been placed on the bed of the mould before charging.

The mould head is brought over by hydraulic pressure, the ram is raised, and the meal formed into a flat rectilinear cake. Another piece of press bagging is placed on the top, and the cake is removed by means of a tray.

PRESSING: A.A. PRESSES.

The moulded cake is next placed between two of the plates of the press. The press may hold fifteen or nineteen cakes, and when full, is closed by hydraulic pressure at 700 lb. per square inch. When the maximum low pressure has been reached, the oil commences to flow feebly from the press. The pressure is then increased to 5,000 lb. per square inch, and the oil commences to flow more rapidly. When the oil flow finally ceases, the press is "dropped" and the cakes removed and stripped of the press bagging.

PARING.

The cakes at this stage have oily edges, which must be pared off and returned to the cooker. This is carried out by a machine fitted with a reciprocating knife. When the cake is held in position on the parer table, the knife trims the inner edge. Each edge is held against the knife in turn.

CAKE NUTTER.

The pared cakes are now fed by hand into a nutter which reduces the cake to lumps, which will pass through a one inch sieve.

CAKE COOLER.

Immediately before cooling, the fine meal is removed by means of a quarter inch screen. After cooling, the meal is returned to the main feed, en route to the weighing machine.

WEIGHER.

The weigher is semi-automatic, the cake being weighed at 1½ cwt., whilst the bag is still attached. The bags are then taken from the weigher, stitched and labelled for delivery as nutted cake.

AGITATOR CAKE.

It is now necessary to retrace our steps to the hydraulic presses in order to follow the treatment of the oil.

The oil, expressed from the cake by the press, plus some of the meal, has found its way by means of channels to a tank. The tank is specially constructed with a semi-circular base.

A slow moving series of paddles turn on a shaft set inside the tank. These keep the oil moving, and so the meal present is kept in a state of suspension.

OIL FILTER.

The solid matter present with the oil has now to be removed. The oil is pumped to a filter, the pressure exerted by the pump forces the oil through canvas sheets, whilst the solid matter is trapped in the filtration chambers.

From time to time, the filter is opened up, and the cake and meal deposits are scraped from the canvas faces and returned with the parings to the kettle. The filtered oil now passes to a store tank to await dispatch to the refinery.

Decorticated Cotton Cake 49%

Earlier chapters have dealt with decortication, removal of foreign matter, delinting and storage. It is fitting that these features should be shown in their relationship to subsequent processes.

The sequence of linseed and black cottonseed processing has already been dealt with, and this section deals with a similar application to decorticated cottonseed, using the woolly varieties, such as East and West African.

Cottonseed is usually stored in silos, and before any processing, foreign matter must be removed.

A stone remover of the closed circuit type is first met with, the seed being conveyed by gravity buckets and worm. Natur-

ally, iron and other metals are also separated with the stones, but nevertheless, the seed should pass over a magnet as the stone catcher will not remove small pieces of iron, or those pieces with large areas and small mass.

The seed is now ready for the ginning process, where a portion of the lint is recovered, and the ginned seed passed to the decorticating plant. The diagram shows lints and hulls as by-products of their processes, but does not indicate subsequent treatment. Lint is usually baled direct, and its ultimate treatment need not concern us at this point.

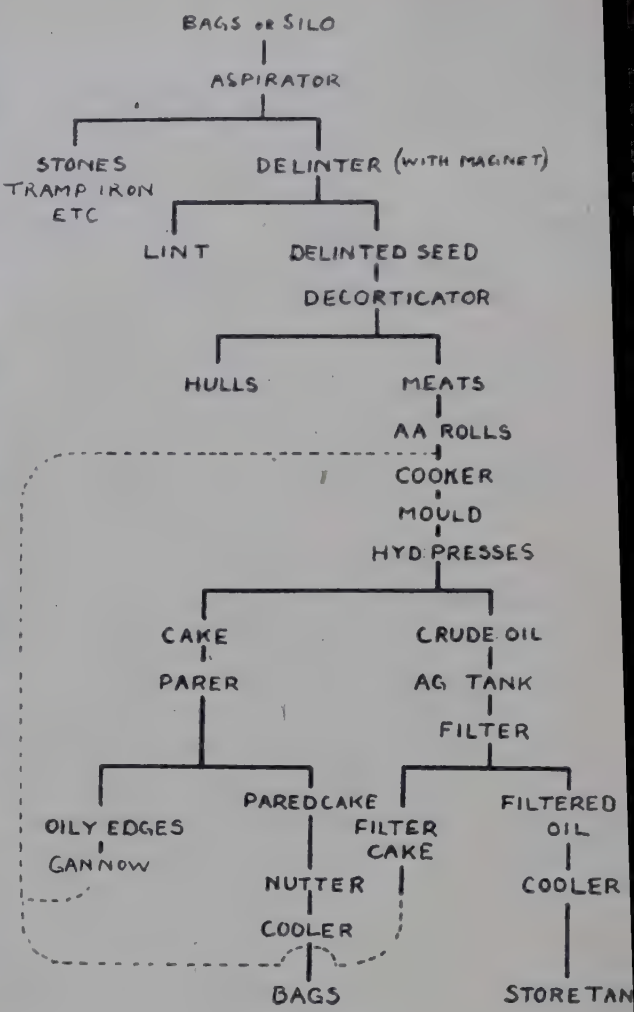


Fig. 24

The hulls may be baled as produced and used, if sufficiently woolly, for upholstery, or alternatively, if special grinding equipment is available, they may be reduced to a fine meal and hull fibre.

The meats produced are now ready for Anglo-American rolling direct. The A.A. rolls reduce the meats to small flakes about .008 inch thick, as this thinning process tends to prepare the meats for the giving up of the oil. The rolled meats then pass to a cooker or steam kettle.

In the cooker, the temperature of the rolled meats is raised to about 190 degrees F. by the application of live and jacket steam, and the meal is now ready for the hydraulic presses.

Moulding is carried out in the same manner as used for most seed. The moulded cake, with press cloth on the top and bottom faces of the cake, is then placed by hand between the plates of the press. The press; when full, is allowed to close slowly in order not to spread the material when under pressure. After receiving a suitable pressing, the cakes are stripped and

pared, the parings returning to the cooker, via a gannow, where they subsequently join up with the new material. The finished cakes are then nutted and cooled. The cooled cake is fed to a grinder if meal is required, or bagged direct if intended for sale as nutted cake.

The oil follows a similar path to that shown in the linseed sequence, and the filter cake or solid matter separated from the oil is returned with the cake parings to cooker.

Undecorticated Cottonseed

Undecorticated cottonseed cake can be obtained by the use of two methods, one of which is only employed when the final cake is required as a meal, say, for compound cake manufacture. The second method will produce slab cake or nutted, as required.

This second method involves less machinery, and is less complex in its sequence, but unless special scrubbing machinery is available, only black or Egyptian types of cottonseed should be used.

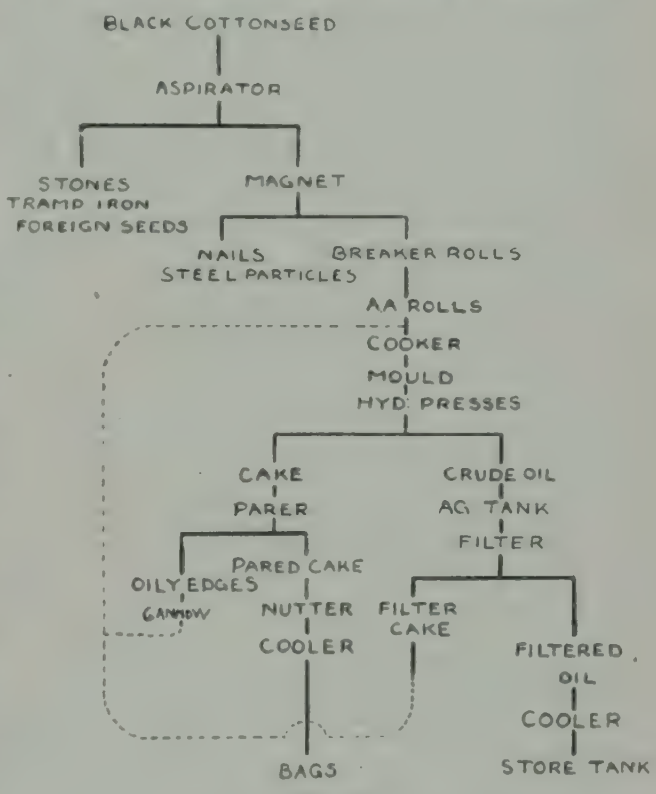


Fig. 25

The sequence shown indicates that black seed is to be processed and as its lint content is very low, delinting is not necessary. The seed has been screened on the bulk intake plant, and here, very large stones, pieces of wood, etc., are removed.

The partially dressed seed now lies in a large silo, and is delivered by means of worms or conveyors to a stone trapping aspiration plant where all medium-sized foreign matter with a greater density than the seed is removed. The aspirator, however, does not always separate tiny pieces of metal, such as slivers of steel and iron produced in the machinery, and small nails and screws which seem to be an inevitable and unfailing companion of bulk cargoes of all types of seed. To complete the final cleaning operation, the seed is passed over a cascade magnet where the offending small ironware is effectively removed.

The seed next passes through breaker rolls where it is reduced to a size which aids Anglo-American rolling. The breaker and A.A. rolling will be described in greater detail later, and at this point, we will merely assume that the seed has been flaked or thinned in order to assist oil expression.

The rolled material passes to the cooker or kettle where with the aid of live and jacket steam, the temperature is raised and the hot meal passed automatically to the cake moulds. Here the cake is moulded to the size necessary for pressing, and press cloth is also fitted.

The moulded cake passes to the presses which are operated in batteries of four, six, or more, according to the mill design.

After pressing, the cakes are pared to remove oily edges, and the finished cake untied and cooled. If the cake is required in slab form, the nutting is dispensed with and the slabs are placed in racks for a specific period and, when cooled, they are weighed and dispatched in half ton lots.

In the meantime, the oil, which follows a different path, is collected in a trough and passed into the agitator tank. The crude or unfiltered oil is pumped out of the tank and into a filter, which separates the fine particles of cake from the oil. The filtered oil is usually passed over a cooler to reduce its temperature, and thereby assist storage before the refining process. The cake meal separated from oil by filtration is passed back into the cooker and mixed in with the new supply of seed.

The oily edges which have been pared off the cakes are reduced by a gannow, or alternatively, a grinding mill, and the meal produced usually follows the same return path as the filter cake.

CHAPTER X.

THE NEED FOR REDUCING MACHINERY FOR OIL BEARING SEED

The primary object of the seed crusher is obviously to remove the valuable oil from seeds and nuts. The methods used will be dealt with more fully as applied to the different types of seed processed.

Each type of seed, or nut, confronts the crusher with specific problems for its general group, but variations within that group, e.g., different varieties of ground nuts, raise special problems which will be dealt with at a later stage. The types of seed differ in almost every conceivable way.

In deciding the treatment necessary, the fullest information

concerning the seed or nut should be obtained. A complete analysis is necessary, as much of the subsequent treatment will be influenced by this. In addition to the analysis, the size of the nuts or seeds is a very material factor, as also is the capacity for delivering up or retaining oil content.

The oil content is, perhaps, the chief point in the analysis, as this feature tends to indicate whether single, double, or treble stage processing is desirable or economical. Oil content alone, however, would not be a sufficient indication. For example, while decorticated ground nuts and palm kernels have approximately the same oil content, it would not be possible to process both these nuts on similar lines. Ground nuts, for instance, tend to give up oil fairly easily, whilst palm kernel requires intensive treatment before oil will flow.

Other analytical data, chiefly the fibre, albuminoid or protein and moisture content, also play a definite part in guiding the seed crusher as to the essential preliminary processing.

The high albuminoid content, such as that of ground nuts, indicates that too rough handling by rolls will turn the material easily into a soft, unworkable mass. On the other hand, a high fibre content indicates the need for intensive reduction of the texture.

Two other characteristics are of great importance, since they influence the use of reduction machinery to as great a degree as those items of analysis already mentioned. These two characteristics are :

(1) Size of nuts.

(2) Strength of cellular construction.

If the nuts are large in size, progressive reduction is necessary, and this involves the use of machines additional to those which produce final rolling. The final reducing operation, i.e., rupturing of the oil cells, must be carried out whatever the type of seed being processed, though not always before the first crushing stage.

In the case of rapeseed or linseed, Anglo American rolling only is necessary ; in the case of sesame seed, only partial reduction is desirable in the first crushing, and total rolling should take place before the final crushing stage.

Where copra is processed, the gannow or impact breaker has to be used before the material can be ground or breaker rolled. Copra, the dried flesh of the coconut, usually arrives in the United Kingdom as halves or thirds of nuts and the overall size of the pieces may be as large as four or five inches. Gannowing reduces copra to pieces of approximately one inch overall size. This is a convenient size for grinding or breaker

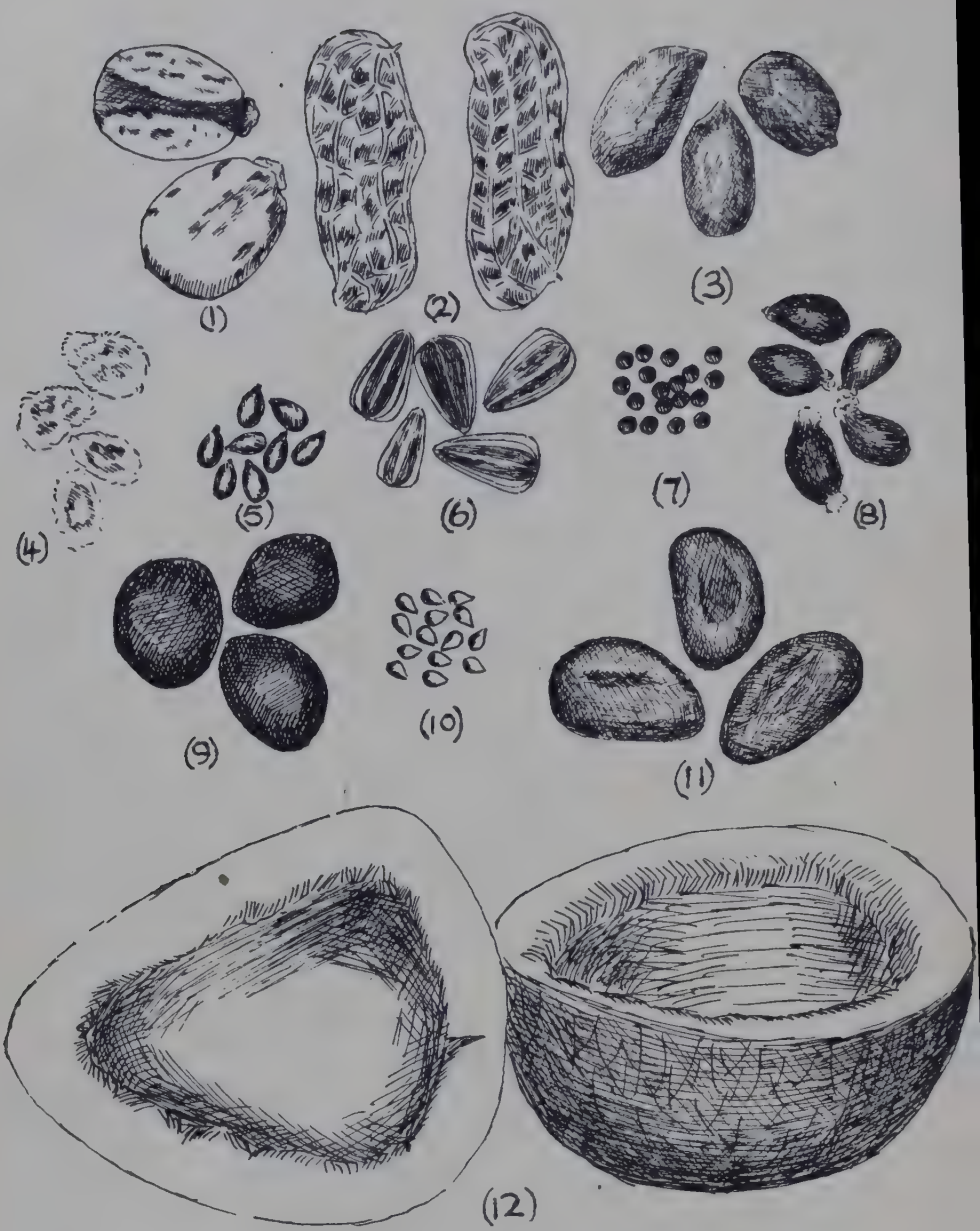


Fig. 26

(1) Castorseed. (2) Groundnuts in shell. (3) Decorticated Groundnuts. (4) Woolly Cottonseed (*G. Hirsutum*). (5) Linseed. (6) Sunflower. (7) Rapeseed. (8) Egyptian Cottonseed (*c. Barbadense*). (9) Palm Kernels. (10) Sesame. (11) Cocoabeans. (12) Copra.

rolling, after which a preliminary process of oil removal is carried out. A.A. rolling is only used after completion of the first oil removal process.

Palm kernels present a different proposition. The oil content is high, but such is the strength of the cellular construction that only the most thorough Anglo American rolling will result in the liberation of any of the oil at all. Moreover, at each crushing stage, extra rolling is necessary.

Seeds containing a hard outer shell would fall into two classes for the purpose of the present work :

(1) Undecorticated.

(2) Decorticated.

The subsequent treatment of decorticated seed is different from that of undecorticated, this being due to changes in shape and size, as well as changes in analysis.

Decorticated seeds do not require much treatment before Anglo American rolling, as, usually, they are partly reduced in the decortication process. The concentration of the oil and albuminoids, however, may make it desirable that oil removal takes place in two or more stages. Undecorticated seeds are, generally speaking, best suited to single stage crushing.

Classification for Purpose of Pre-treatment

Anglo American Rolling only :

Linseed, Rapeseed, Undecorticated Kapoc.

Breaker and Anglo Rolling :

Undecorticated Cottonseed, Undecorticated Groundnuts, Soya Beans, Babassu.

Gannowing, Breaker Rolling, First Stage :

Copra.

Grinding and Anglo American Rolling :

Palm Kernels.

Breaker Rolling Only, First Stage :

Decorticated Groundnuts, Cocoa Beans, Shea Nuts.

CHAPTER XI.

REDUCING MACHINERY

While the object of the seed crusher is principally to remove oil from nuts and seeds, each type of seed or nut confronts the crusher with specific problems; each type differs in almost every conceivable way and the amount of oil possessed by the seeds influences procedure to a large degree.

The fibre, albuminoid and moisture contents also play a definite part in guiding those who remove oil and produce a resultant cake, whether for use as a cattle feed or as fertilizer. Two other important characteristics are worthy of mention as they influence the processing possibly to a greater degree than that of analysis quoted above. They are :

(1) Size of seeds or nuts.

(2) Strength of cellular construction.

If the nuts are large in size, progressive reduction is necessary, and this involves the use of machines additional to those

which perform the final reducing operation common to eve type of seed. The common reducing operation, i.e., the ruptu ing of the oil cells, must be performed whatever seed is bei processed, though in most cases the stage at which the c rupturing is carried out is determined by the number of pressin processes and by the analysis as stated above.

Only the smallest types of oil seed can be rolled effectivel on Anglo-American rolls without pre-treatment, notabl linseed, rape and sesame. Those seeds or nuts requiring pre treatment may be listed as copra, palm kernel, ground nuts, sun flower, shea nuts and castor seed.

Reduction of this second group can be obtained by the use of breaker rolls, with the exception of copra which will require the use of a gannow or similar breaking machine. The rolling of undecorticated cottonseed is also improved by pre-treatment with breaker rolls.

The Gannow

This machine is simply but stoutly constructed. It consists of an overall cast-iron carcase, open at the base, and bolted to floor girders surrounding a hopper below. Two or four sets of beaters, or swing hammers, are mounted on shafts secured to end plates; the end plates on the one side by the motor shaft plus a bearing, and on the other by an external carrier bearing.

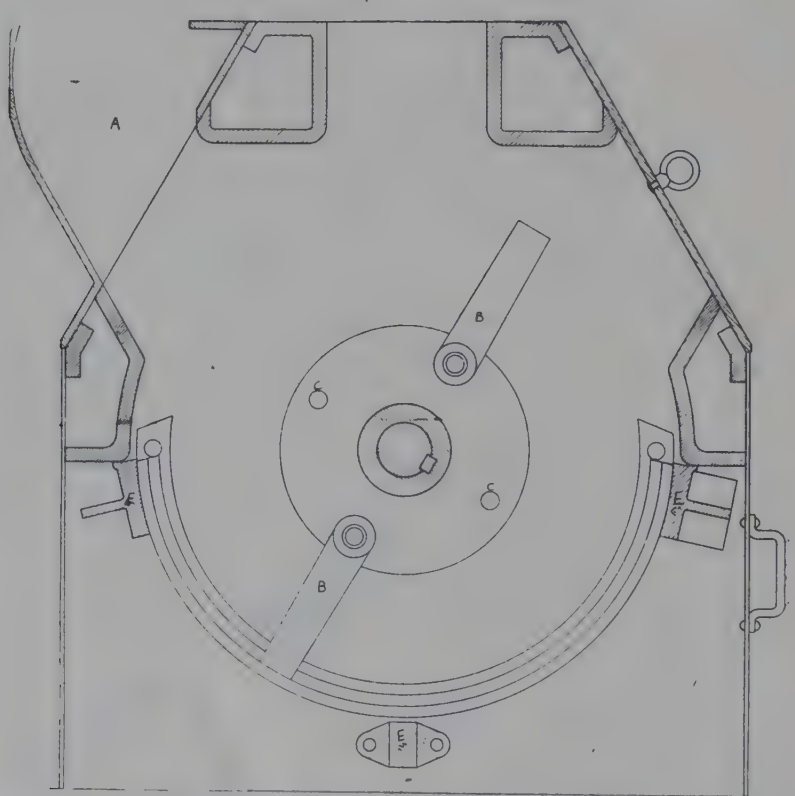


Fig. 27. Gannow—Side Elevation

In the lower half of the casing, a set of strong bars of one inch, 1⅛ inch, or 1¼ inch diamond section and semi-circular shape are mounted from the sides and bottom centre. The semi-circle of the bars is on the same centre as the beaters or hammers. The centrifugal force is so great that the beaters, though free to move on the shaft, strike the nuts with an impact

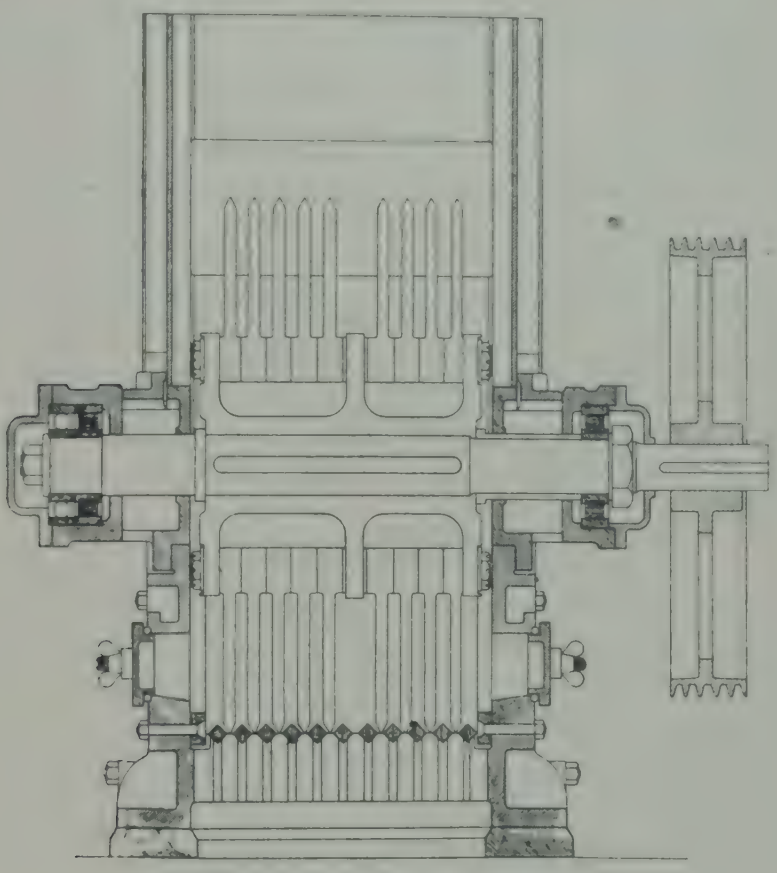


Fig.28. Gannow—End Elevation

only a little less than if they were rigid. The swinging action of the beaters absorbs the shock of impact and saves them from damage.

When the nuts are sufficiently reduced, the pieces are thrown through the narrow spaces between the bars. The capacity of a large gannow is about three tons per hour.

After gannowing, copra should be reduced to pieces no greater than one inch in any dimension. A gannow dealing with three tons of copra per hour requires about 20 h.p.

The side elevation of gannow (Fig. 27) shows the inlet hopper on the left-hand slope. This inlet can be changed to the right-hand side of the machine with little difficulty.

The beater (B) will work in either a clockwise or anti-clockwise direction. Two sets of beaters only are shown and they are in their extended positions. The holes (C) enable

two additional sets of beaters to be added if required. The longitudinal shape of the bars can be seen clearly and the beaters extend to the centre line of the bars.

The bar mountings marked (E) show the three points at which the bars are secured.

CLEANING.

After working corpa continuously for many hours, the housing below the bars tends to become clogged with fine portions of the nut. To remove this material, the side panels can be unbolted quickly and after cleaning can be as quickly bolted up again. The area swept by the beaters is automatically cleared by their action. The carcase and beater carrying casting are shown in section, as well as the bars and driving wheel (Fig. 28).

There are nine beaters on each shaft which centre in the spaces between the bars. The beaters become worn with continuous use and require replacing at intervals, as short beaters will not sweep the area perfectly and the material cannot be beaten through the bars correctly. The shaft travels at a speed of 700 to 900 r.p.m.

Breaker Rolls

These rolls are among the most useful machines in the equipment of the seed crushing mill, and the most popular method of pre-treatment for seeds such as ground nuts and cottonseed, if undecorticated, is breaker rolling.

The object of breaker rolling is to reduce the seed to a size which will easily enter the top roll of the Anglo-American unit. Ground nuts are usually reduced to portions which constitute about eight pieces from each nut. Cottonseeds are halved, or sometimes merely burst open and partly flattened.

A set of breaker rolls may be of the single tier (two rolls) or two tier (four rolls) type.

Two chilled iron rolls 3 ft. long by 14 inches diameter are mounted in a large boxlike carcase. Each roll has deeply cut grooves running lengthwise in a spiral direction. The spiral forms an angle of 50 degrees with the vertical end of the rolls. The groove has a V-shaped section, one side of the V being on the diameter line of the roll, the other forming an angle of 60 degrees to this. The depth of the V is 3/32 inch while the number of teeth formed by the cuts is 180.

Seen in section, the teeth point in the same direction on each roll, and the rolls turn in opposite directions, i.e., both rolls run inwards towards each other. By this means, the right-hand surface of the front roll and the left-hand surface of the back roll are travelling in the same direction. The back, or fast roll

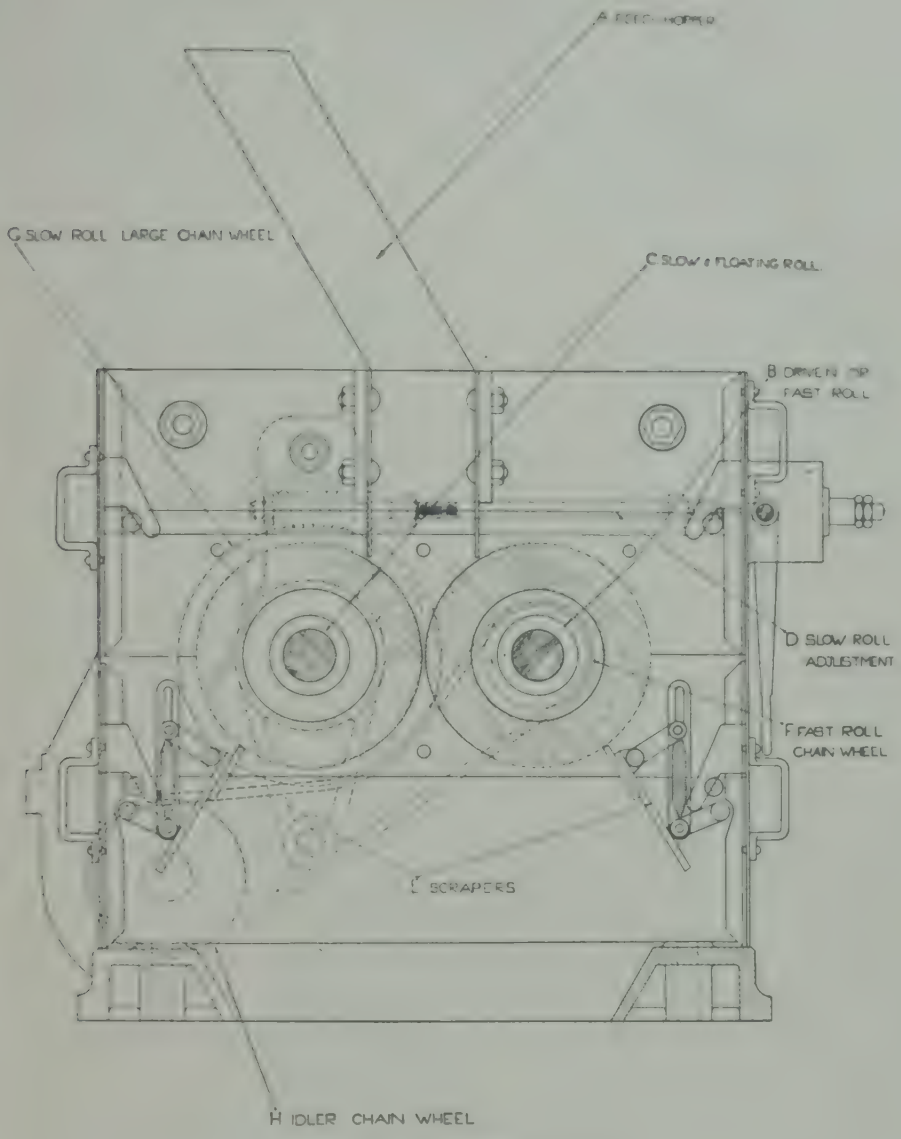

G SLOW ROLL LARGE CHAIN WHEEL
C SLOW & FLOATING ROLL
B DRIVEN TOP FAST ROLL
D SLOW ROLL ADJUSTMENT
F FAST ROLL CHAIN WHEEL
E SCRAPERS
H IDLER CHAIN WHEEL

Fig. 29. Breaker Rolls

travels on fixed bearings at 500 r.p.m. and is driven by a 20 h.p. motor. The front roll speed is 200 r.p.m. and is driven by means of a chain from the fast roll shaft. The front roll bearings are mounted on stout steel arms which pivot from the base of the casing. The tension rod device is mounted between the pivoting arm at the top and the casing on each side. This facilitates accurate adjustment of the distance between the rolls by turning the nuts on the tension rods.

Any slack in the driving chains caused by adjustment of the rolls is taken up by a carrier wheel which can be adjusted to suit. It is desirable to mount a feed roll over the machine to ensure an even feed over the total cutting length of the rolls. By this means, maximum efficiency and evenness of wear is obtained.

A cam shaft connects the two tension rods, and by mea of a handle on this shaft, the operator can release the tensi instantly if desired. In addition, if a bolt or other piece foreign matter should find its way into the feed, the cam w automatically turn, causing a release of the tension which sav the rolls from serious injury.

The life of the rolls depends upon the hardness of the material being reduced and the degree of breaking obtained. Palm kernels would blunt a set of rolls much quicker than ground nuts. The life of the rolls, therefore, may vary from, say, two months to twelve months.

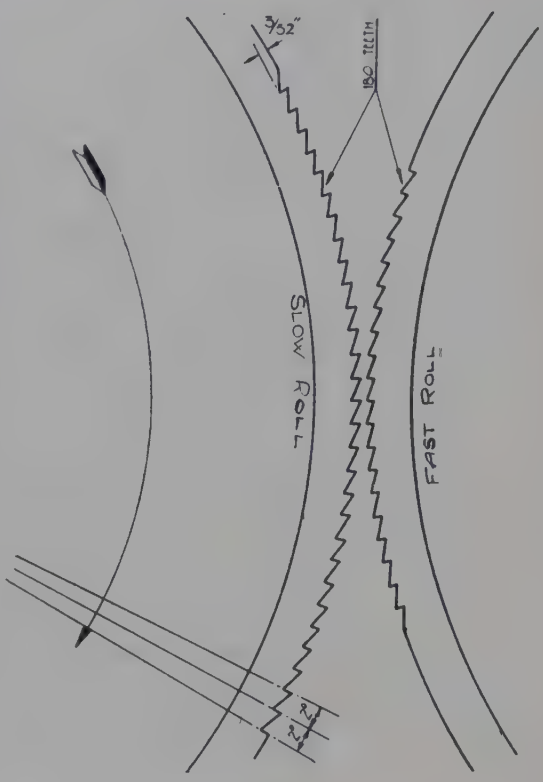


Fig. 30. Outer Face of Breaker Rolls

When the teeth are blunted, the rolls must be replaced by a reconditioned set while the worn rolls are sent to the engineering shop for recutting on a lathe. Reconditioning of rolls can only be carried out until the depth of the chill is reached; afterwards, the roll must be scrapped.

Fig. 29, showing a complete set of breaker rolls does not give a very clear idea of the formation and direction of the teeth of the rolls. The supplementary illustration (Fig. 30) is an enlargement of the outer face of both rolls in the correct position.

Note the upward projection of teeth on the slow roll tending to hold the nuts, the breaking being carried out by the higher speed and forward direction of the teeth on the fast roll.

Feed Rolls

Both breaker rolls and Anglo-American rolls require an exactly regulated and distributed feed if they are to give an efficient performance. If, for instance, a set of rolls has been

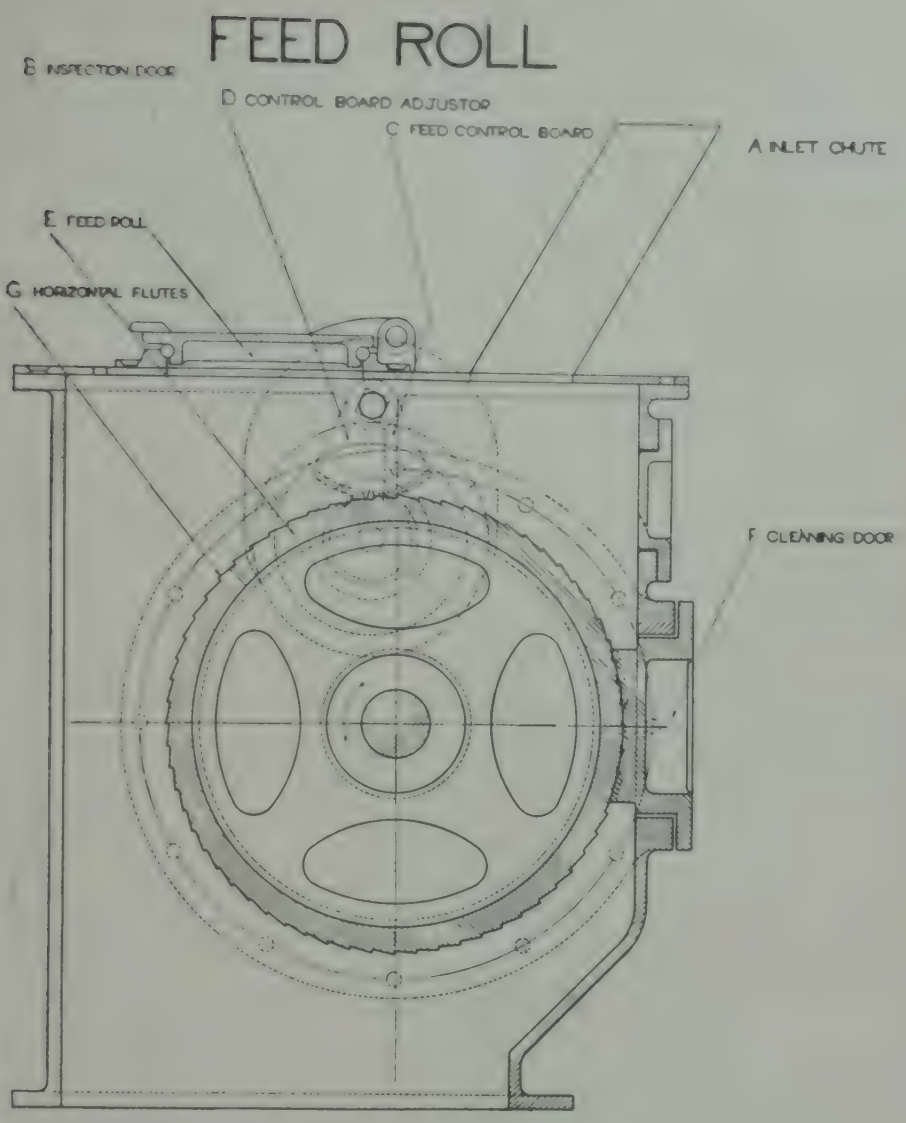


Fig. 31

adjusted to produce a certain quality or fineness of texture at, say, 1½ tons per hour, the quality is only constant for that particular rate of flow. Should the feed be increased to, say, two tons per hour, the quality will be changed immediately, possibly with disastrous results.

It is important also that the feed be distributed along the entire length of the rolls, in order to ensure evenness of wear. Feeds may be regulated in many ways, but one of the best ways of obtaining an even, regular feed lies in the use of a feed roll.

The feed roll shown in Fig. 31 is two feet in diameter, and the grooves cut on the outer surface grip the feed and carry it forward in an anticlockwise direction. The adjuster board can be moved away from the roll by turning a hand-wheel which operates a quadrant fixed on the board pivot.

The speed of the feed rolls is 5 r.p.m., provided by a 1½ h.p. motor.

Anglo-American Rolls

The purpose of Anglo-American rolls is to break down fibrous structure of oil seeds. The oil content is enclosed small cells in the fleshy portion of the seeds and the streng of the cellular construction varies with different types of see Some types will break down very easily when light pressure applied, whilst other types will require a very high pressure.

Ground nuts and palm kernels come most readily to mi as examples of this difference. In ground nuts, the me pressure of the finger and thumb is sufficient to crush many

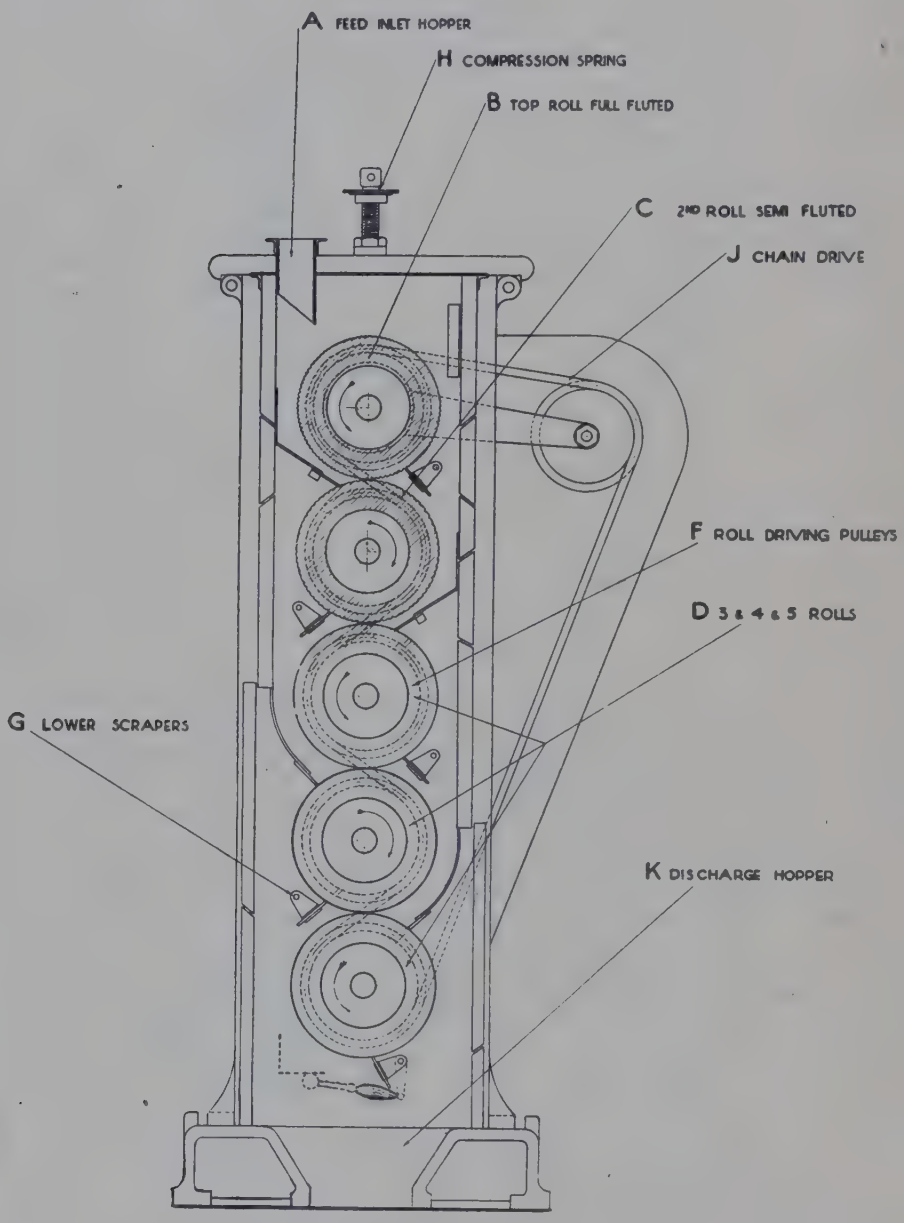

A FEED INLET HOPPER
H COMPRESSION SPRING
B TOP ROLL FULL FLUTED
C 2ND ROLL SEMI FLUTED
J CHAIN DRIVE
F ROLL DRIVING PULLEYS
D 3 & 4 & 5 ROLLS
G LOWER SCRAPERS
K DISCHARGE HOPPER

Fig. 32. Sectional View, A.A. Rolls

the oil cells, this being due largely to the fact that the oil cells are composed mainly of protein, the fibre content being very low indeed. Most analyses show these features to be: Albuminoid 25 to 28 per cent., and fibre one to two per cent. The weakness of the ground nut structure makes it possible to remove much of the oil without complete destruction of the cells by means of Anglo-American rolling. Indeed, if ground nuts are thoroughly rolled in the first instance, the resulting mass is so soft that it will not stand up to the application of pressure either by expellers or hydraulic presses.

The palm kernel, however, is an entirely different proposition, despite the fact that the oil content is very similar to that of ground nuts, i.e., ground nuts 46 to 48 per cent. oil, and palm kernels 48 to 50 per cent. oil. Against the values quoted for ground nuts, however, it should be noted that palm kernels contain nine to ten per cent. albuminoids and six to seven per cent. fibre.

The fibrous wall of the palm kernel oil cells is so strong that only the most efficient reducing machinery can hope to render these seeds suitable for processing either by expellers or presses.

The Machine Unit

A complete machine may consist of three, four or five separate rolls. These rolls are mounted vertically on semi-fixed or floating bearings. A strong cast-iron frame at each end carries the bearings in a vertical trough.

The bearings of the bottom roll rest on the base of the vertical trough. The next roll rests on the bottom roll, and its bearings are held in place by the walls of the trough but are free to move vertically. All the other rolls are fixed in a similar manner, and in this way each roll exerts its full weight on that immediately below. In this way, the total weight of the four top rolls rests upon the bottom roll. The pressure exerted by the mass may be further increased by means of a powerful compression spring marked H (Fig. 32). Each roll weighs approximately 17 cwt. The total pressure exerted on the bottom fixed roll, therefore, is 4 × 17 cwt. = 3 ton 8 cwt. without the use of the compression spring.

Rolls are made of chilled iron and are shrunk on to their central shafts. Roll diameters are as follows: Nos. 1, 3 and 5 rolls, 17 ins.; Nos. 2 and 4 rolls, 16¾ ins. Each roll measures 7 ft. 6 ins. in length.

While it will be noticed that the first, third and fifth rolls are of larger diameter than the second and fourth, the driving pulleys or gear wheels are of a size which ensures the same peripheral speed on all rolls. By this means, any surface fault

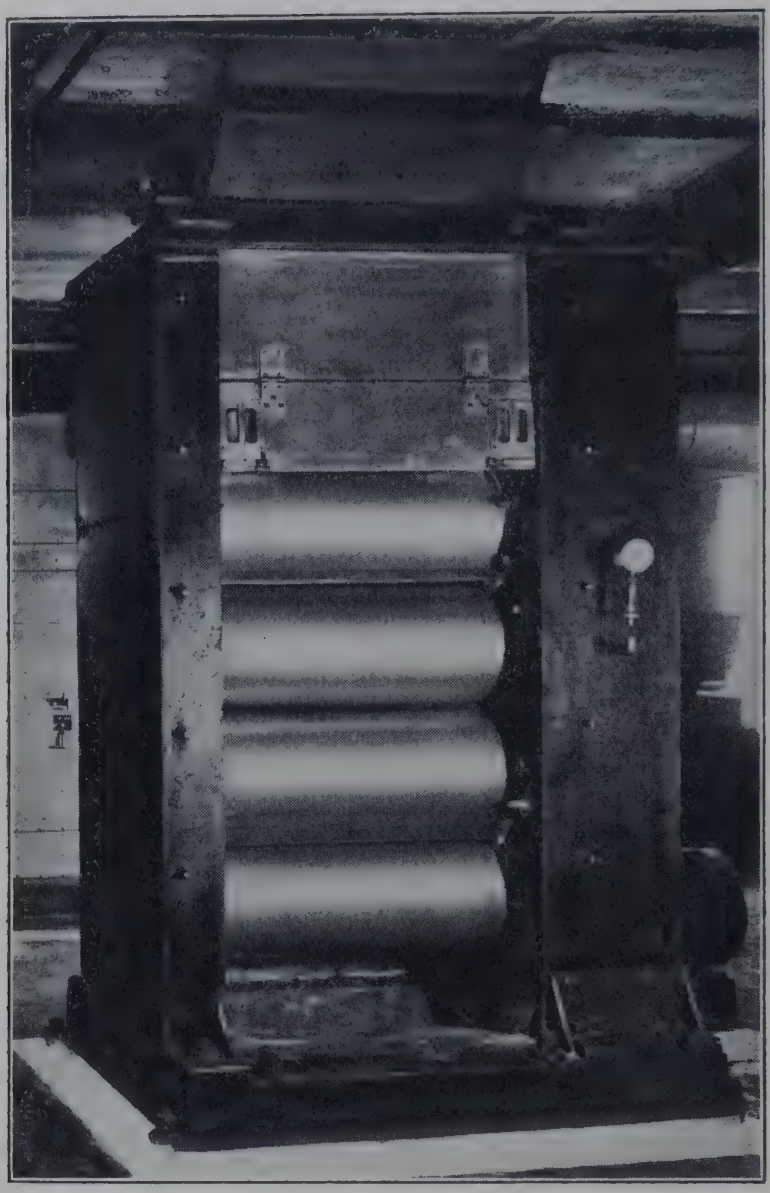


Fig. 33. Anglo-American Rolls

on a particular roll is prevented from contacting the next ro in the same place at each revolution. If this were not so, faulty surface on one roll, by continuous contact on the nex roll in the same place, would cause a fault to appear on tha roll. A fault may take the form of a minute " flat " or a fain chip off the surface of the roll.

Fig. 32 shows the method of driving the unit, and th direction and method are the same for both chain or belt drive

The chain passes round the toothed wheel of the top ro in an anti-clockwise direction, and crosses over to the opposit side of the wheel on the next roll which, therefore, turns i

clockwise direction. The chain then crosses over to the next wheel, and so on, until, after passing around the wheel on the bottom roll, the linkage is completed by passing the chain around a jockey pulley projected by an arm from a point almost opposite the top roll.

Projected against the surface of the second roll, and shown in the illustration about 12 degrees to the left of the contact point of the roll, is a metal plate known as the "cut." Each succeeding roll has a cut mounted on opposite sides. The purpose of the cut is to intercept the feed which is tending to drop downwards, and to drive the material on to the top portion of the roll. The clockwise motion of the second roll carries the material forward and between the second and the top rolls.

Upon emerging from between these rolls, the partly flaked or flattened material drops to the second cut mounted on the third roll, where the same operation is repeated. As each cut performs its function, the material is rolled a little finer and, at the fourth cut, the necessary fineness is obtained.

The flutes on the top roll may be $\frac{1}{2}$ in. or $\frac{5}{8}$ in. apart and these run in a spiral direction along the roll. The purpose of the flutes is to grip the seed and induce it to travel through the contact point between the rolls. The second roll is semi-fluted, which means that the space between the flutes is twice that of the top roll. The third, fourth and fifth rolls are smooth, the reason for this being that flutes become unnecessary as the material is thinned out and easier to roll.

The purpose of the spring loaded scrapers on the underside of the rolls opposite the cut is to remove any material which tends to cling to the upper roll. The material scraped off the roll falls with the main feed to the next cut.

In the case of linseed and similar small seeds, a flute roll may be dispensed with and a semi-flute used in the top position. The remaining four rolls will then be smooth. Seeds such as linseed are comparatively easy to feed into the top cut, and do not require the additional inducement of a fully fluted roll.

The flakes of rolled material may vary between .005 in. and .008 in. in thickness.

CHAPTER XII.

HYDRAULIC PRESSURE

Before dealing with the oil mill hydraulic press in particula a general statement on the principles governing this process w be useful.

The hydraulic press is one of the main mechanical co trivances of modern times. Probably, it is the most strikin example of cumulative energy known. By its means, a chi may lift a ton, not in one lift, of course, but by a series of sma lifts. Most great weights are lifted, or high pressures obtaine by the use of hydraulic power. The most popular medium use is water, probably on account of its cheapness and abundanc

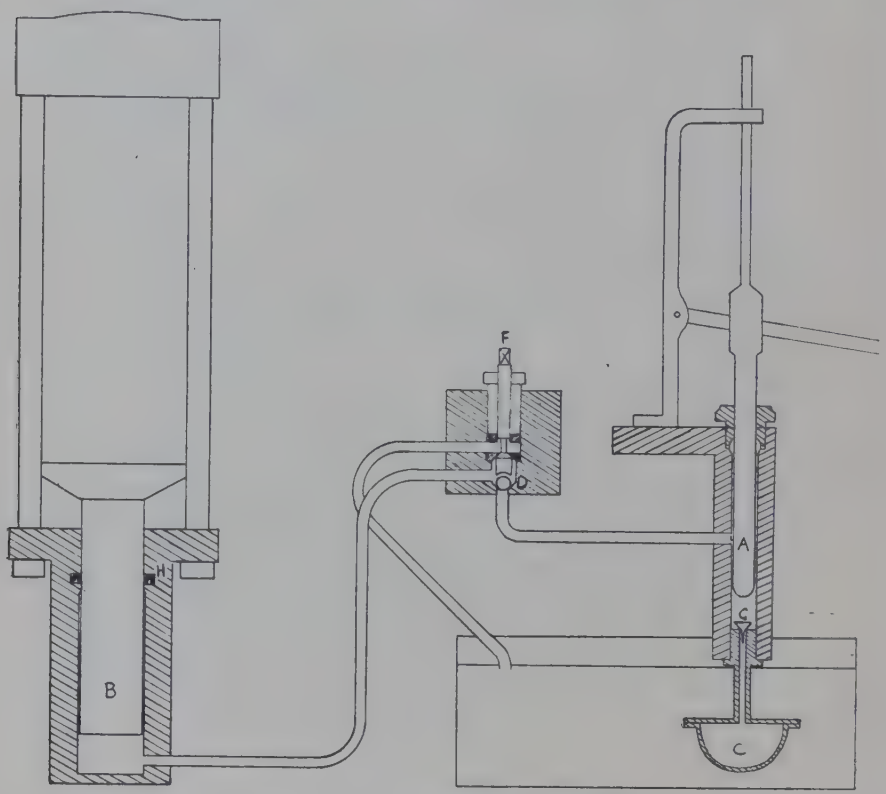


Fig. 34. Hydraulic Hand Press

The seed crusher, however, uses oil for pressing purposes for a variety of reasons :

(1) Oil preserves the machinery ; water may rust it.

(2) Oil lubricates the moving parts.

(3) Possible contamination of the expressed oil from seed by the pressure oil in the event of leakage is not as serious as water contamination.

(4) The higher viscosity of oil makes leakage less likely.

The action of the hydraulic press depends upon the principle discovered by Pascall that a pressure exerted upon a liquid in a closed vessel at any point is communicated equally to every point of surface of the container. The chief difficulty which confronted the early designers was not how to produce sufficient pressure, but how to prevent the liquid from leaking between the cylinder wall and the ram. The solution of this difficulty was discovered in 1795 by Joseph Bramah, a Yorkshire engineer, and it was his invention which enabled the hydraulic press to revolutionize the industry.

Bramah invented the packing leather, a circular piece of leather with a U-shaped section (Fig. 35). This ring is recessed in the cylinder wall near the top. The pressure of the liquid which flowed under the packing caused the sides of the packing to distend until they pressed hard against the back of the recess, and the wall of the press ram. A strip of felt inserted in the U section assists in keeping the walls in a distended position.

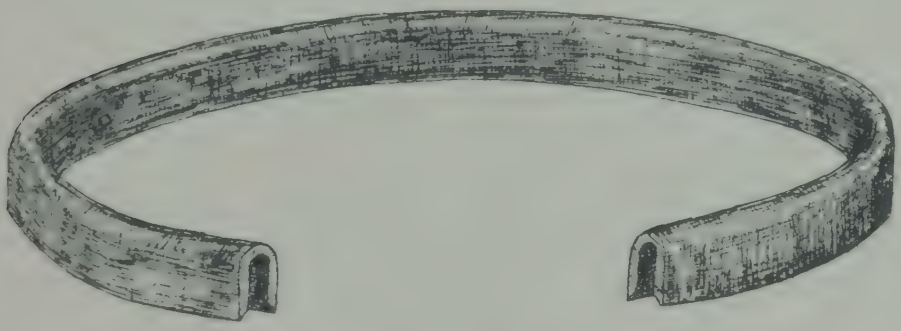


Fig. 35. Hydraulic Press Packing Leather

The Hydraulic Press

A simple form of the hydraulic press system is shown in Fig. 34. The pump is of the hand type, and is worked by a lever which is a mechanical advantage to the operator in that he can exert a force on the ram A, many times greater than his strength would permit if he pushed the ram down by direct pressure. At the lower aperture in the pump cylinder is a valve G, which rests neatly in the space and seals off the inlet when the ram is travelling downwards.

The down stroke of the pump forces oil out of the pump cylinder, while the pressure set up in the cylinder lifts the ball valve D and allows oil to flow into the cylinder of the press. As soon as the upward stroke commences, the oil in the pump cylinder is no longer under pressure, and immediately the atmospheric pressure on the oil in the supply tank in which the sump C is immersed pushes the valve G up from its seat, oil flows into the cylinder. The flow continues until the finish of the stroke. At the same time, the pressure exerted by the resistance

of the press ram pushes the ball valve hard on to its seat, where it remains until the down stroke of the pump exerts a greater pressure on its underside than that on the press ram side. Note the U leather at H recessed in the cylinder wall to prevent leakage.

The pump ram has a much smaller diameter than the press ram. Consequently, one stroke of the pump will only succeed in lifting the press ram a very short distance. It follows, therefore, that very many strokes would be necessary to lift the ram of the press through any appreciable distance.

Until the press is fully closed and the material in the press is actually being compressed, the resistance is equal to the weight of the ram, plus the material due for pressing, which is resting upon the ram table. The pumping operation would be continued until the maximum pressure allowed by the strength of the structure was reached. When the pressing has been completed, the hand valve F is screwed down on the ball and off its seating, immediately below the exhaust pipe. This allows the oil to flow from the press cylinder and the ram commences to drop until it reaches the base of the cylinder.

Those unfamiliar with the principles of hydraulic power may well ask: "Why use a press ram with a very large area and a pump with a very small ram?" The answer to this can best be explained mathematically.

For our purpose, the pump ram has an area of one square inch; the press ram an area of 100 square inches. The operator is capable of exerting a total pressure of 300 lb. on the pump ram, and since its area is one square inch, the pressure exerted on the liquid in the pump cylinder is 300 lb. per square inch. When this pressure is reached, the oil is flowing via the ball valve into the press cylinder, also at 300 lb. per square inch. Every square inch of surface in the press cylinder is, therefore, subjected to 300 lb. per square inch. The total pressure resulting on the ram face is 100 square inches × 300 lb. = 30,000 lb., or 13.33 tons.

The hand method described can be useful only for small experimental plants, but a study of the mechanism involved will enable the student better to understand the more complicated equipment used by the seed crushing industry.

CHAPTER XIII.

THE HYDRAULIC SYSTEM

The previous lecture on hydraulic pressure dealt with general principles and an experimental small scale plant was studied. This chapter will describe the general disposition of the various units in the hydraulic equipment of the oil mill.

Each of the separate units are complicated machines requiring individual treatment if they are to be studied closely. At the same time, it is important that these units should be shown in their relation to each other before dealing with them in detail. If the part played by each of these units is not clearly understood, much of the value of a later detailed study will be lost.

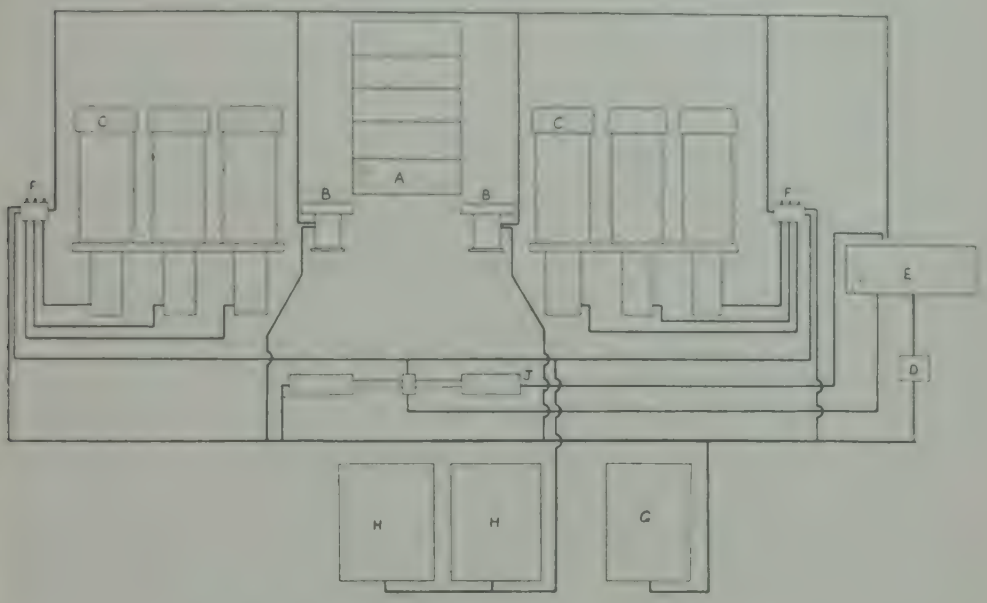


Fig. 36. Hydraulic System—Layout of Units

The processes embodied in the diagram (Fig. 36) are confined to cooking, moulding and pressing. We are not concerned with the value or need for cooking, etc., but a little should be said in order to arrive at the point where the presses function.

A cooker (A) receives rolled meats, and by the application of heat prepares them for pressing. The hot meats, of course, cannot be pressed without converting them from a shapeless mass into a uniform body of cake which can be handled conveniently by the press filler.

A strickling box under the cooker receives a charge of meal while under the kettle aperture. The box, when filled, is shot forward by means of hydraulic pressure, and on crossing the mould frame (B) deposits its load of meal into the mould, at the bottom of which is a piece of pressecloth, after which it returns to the underside of the kettle for another charge. The mould stamper head, also actuated by hydraulic pressure, is swung into place over the meal, and the mould ram, by the same means, lifts the mould table hard against the meal, the pressure forming the meal into a soft cake.

On releasing the pressure and lifting the stamper head, a top wrapper is affixed and the cake lifted out by means of a tray and placed in the press. The type of press (C) used is the Anglo-American, and may contain 15 to 20 plates. A cake is inserted between each plate, and when all spaces are filled low pressure is applied.

It has already been stated that the fluid medium used in the hydraulic system is oil, preferably similar to that removed from the cakes being processed.

The reciprocating pump for generating low pressure has, in some cases, been superseded by the variable speed gear rotary pump (D). This pump is a rather complicated piece of machinery, and will pump oil against a resistance as high as 1,000 lb. per square inch.

The control box (F) has a separate connexion to each press, and by turning the appropriate cock, oil flows from the low pressure line from the pumps into the press cylinder ram which immediately commences to rise. The low pressure is usually limited to 700 lb. per square inch by the use of an accumulator (G).

The accumulator is a large weight mounted on a ram, and is kept suspended by the pressure in the system when 700 lb. per square inch is reached. The accumulator is so linked with the pumps that when its safe height has been reached, the pumps are slowed down until the height drops somewhat.

In the case of reciprocating pumps, the accumulators operate a relief valve for the release of excessive supply. If the accumulator drops too low, owing to the demand exceeding the supply, the pumps are automatically speeded up.

In this way, changes in demand or rate of flow of low pressure are absorbed or compensated. The low pressure oil also drives an intensifier (J) which steps up the low pressure to two tons per square inch.

When the maximum low pressure has been obtained on any press, the control box (F) allows high pressure oil to flow into the press cylinder to complete the final pressing.

The change over from low pressure to high pressure may be automatic or manual. The difference between the two methods will be explained in a later chapter dealing with the hydraulic press control box.

The high pressure system is also equipped with one or two accumulators weighted to obtain an even pressure of two tons per square inch. Should the production rate of high pressure oil exceed requirements, the second H.P. accumulator, weighted slightly heavier than the first, rises to its maximum position and

opens an exhaust valve which releases just sufficient H.P. oil to keep the system balanced.

When a press has received a complete pressing, the cock on the control box is screwed hard down and oil from the cylinder immediately flows to exhaust via the same line between cylinder and control box, then into the oil reservoir (L). It must be remembered, of course, that oil can flow either way in the pipes between the control boxes and the presses, depending on whether the press is rising or falling. Note also that the pipes feeding the accumulators are also two-way flowing.

When the oil flow becomes inadequate, the flow is from the accumulator cylinder back into the line, which causes the accumulator to fall. When the position is rectified, say, by increased volume from the pumps, the direction changes and oil once more flows from the pressure line and into the accumulator cylinder.

The ram again rises and either maintains a slightly varying height for quite a period, according to supply and demand, or repeats the performance described above.

The diagram does not relate the machines in terms of capacity, but merely seeks to show the pathways and positions of the various machines.

The Oil Mill Hydraulic Press

The Anglo-American hydraulic press was first used in the United States and was subsequently introduced into England in 1873. The earliest types of hydraulic press were horizontal, following the design of the old Dutch Wedge press. The meal was simply placed into bags after pre-treatment, and bags placed side by side in the press. The need for economy in floor space, however, brought about the design of a vertical press.

There are two main types of hydraulic press in operation in the industry to-day, the first is the A.-A. type, which is dealt with here; the second is the cage press. The early A.-A. press used bags in which to place the meal, as in the case of the horizontal press. The bags were placed in boxes which were perforated to allow the pressed oil to run clear. The bags were later replaced by press bagging or cloth. The term bagging is simply a survival from the old days of actual bags.

Press bagging is made of wool, camel or goat hair, woven into long, narrow lengths which can be cut to the correct working length from a roll. With the advent of press bagging, plates began to replace boxes, another economical feature.

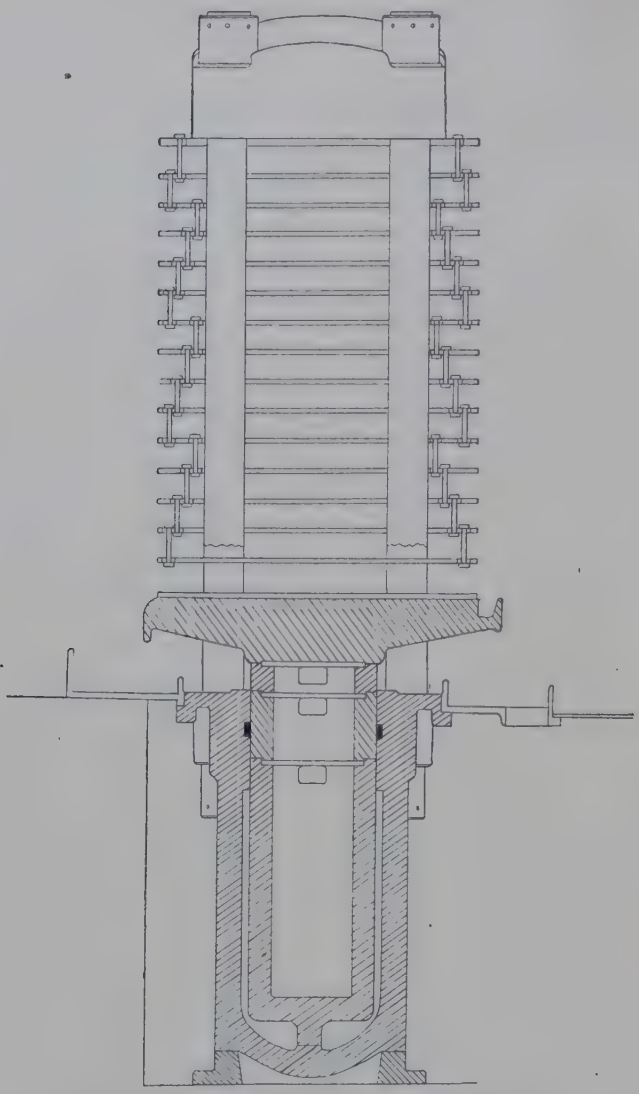


Fig. 37. Anglo-American Hydraulic Press

The Modern Press

The main parts of the press are listed as :

(1) Press Head.

(2) Columns.

(3) Cylinder Base.

(4) Ram.

(5) Plates.

The head is a rectilinear mass of cast steel, measuring about 32 inch × 32 inch with a depth of 17 inch. Holes are drilled in the corners to take the columns.

Four columns, with a cross section 5 inch × 5 inch, are made of forged steel. Both ends of the columns are turned and threaded, and the tops, when fixed in the holes in the head, are held tight with round nuts.

The cylinder is made of cast steel, with a top flange holed in the same manner as the head. The base of the columns is fitted in the same manner as the top.

The cylinder is bored to receive a ram which measures 16 inch in diameter; the top part of the cylinder is a snug fit with the ram, the lower portion being of larger diameter in order to reduce friction as much as possible.

Plates vary in number according to the material to be treated. The top plate is secured to the underside of the head between the columns. The second plate is suspended from the top plate by means of links made of forged steel, which are carried between lugs on the sides of the plates. The succeeding plates are suspended in the same manner. The bottom plate is secured to a stout table mounted on the ram. Plate surfaces are corrugated or studded according to manufacturers' ideas; shaping of the plates in this manner enables the press bagging to be gripped firmly when the press is under pressure, and so limits spreading. Along the top and bottom edges of each plate is fitted a runner which secures the edges of the press cloth and keeps the meal from being pressed out at the sides, as well as easing the strain on the press cloth.

The Pressing Operation

The pressing cycle occupies about thirty minutes. It is desirable that the cakes be under pressure for the longest possible period within the thirty minute cycle; consequently, the emptying and filling of the press should take as little time as possible.

There are two main reasons why this should be so:

(1) The chief aim in the operation is the expression or removal of oil from meal, and the longer the meal can be subjected to pressure, the greater the certainty of removing the maximum amount of oil.

(2) Heat losses due to radiation are severe. Heat is greatest when the maximum area of cake and plate are directly exposed to the atmosphere, as is the cake when a press is open. A rapid filling and emptying reduces the loss to a minimum. Any unnecessary chilling of the cakes before pressing results in oil remaining in the cake which would otherwise be removed.

The mass of metal in the press head is a source of much of the heat loss. If the top cake in the press is examined, it will be noted that the upper surface is lighter in colour, after pressing, than that of the remaining cakes. This cake, on analysis, will be found to contain more residual oil. The light colour is due to the excessive transfer of heat from the hot meal to the steel head. To reduce this loss to a minimum, the head is fitted with a heavily insulated metal cover.

When a press is due to be filled, say, at the start up of t plant, the operator commences to fill the press at a point four five plates lower than the topmost plate, and continues until t bottom plate is filled. A cock in the control box is then turne and pressure oil from the low pressure (700 lb. per square inc line passes into the cylinder, and the ram commences to ris The top cake positions are then filled while the press is closin

If the operation is carried out skilfully, the last cake will b placed in the top position just before the full closure i attained. The closing period may occupy from 1 to 2½ minute depending upon the type of material being crushed.

Up to the point of closure, the gauge on the cylinder does no record any pressure, even though the main system connecte by pipe and control box to the press shows 700 lb. per squar inch. The reason for this is that the pressure in the cylinde cannot exceed the amount caused by the back pressure o resistance on the ram, and this amount is equal to the total weight carried by the ram, i.e., weight of ram, plus table, plus weight of plates, plus cake and press cloth.

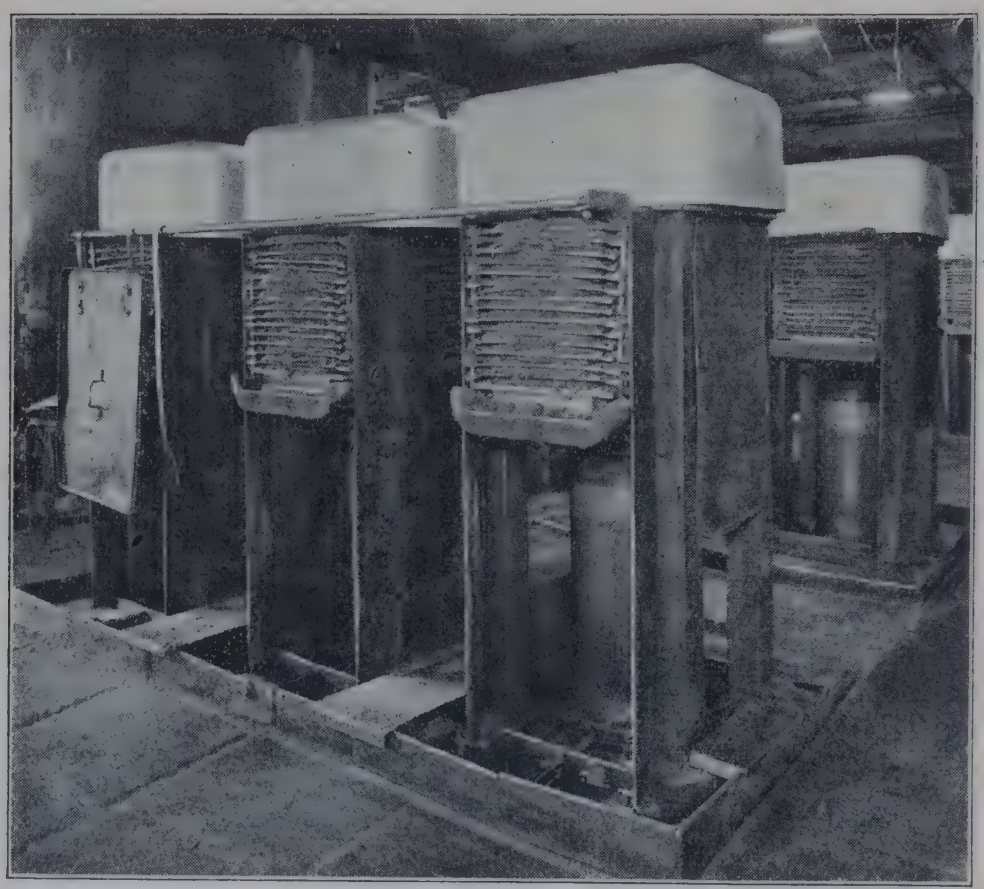


Fig. 38. A battery of Anglo-American hydraulic presses; note hoods fitted over the press heads to reduce heat loss by radiation

The total weight of the items above does not exceed two tons, which, on a 16 inch ram, means :

$$\frac{4{,}480 \text{ lb.}}{201 \text{ square inches}} = 22.28 \text{ lb. per square inch.}$$

On the press fully closing, however, the cakes begin to resist the upward movement of the ram, the gauge commences to show a rapid increase in pressure, and oil commences to flow from the cakes.

When the maximum low pressure of 700 lb. per square inch has been reached, high pressure oil at two tons per square inch is automatically introduced via the control box, and the ram travels higher still, resulting in further compression of the cakes and a more copious oil flow. The total pressure on the ram is now :

201 square inches × 2 tons per square inch = 402 tons.

In a short while, the volume of flow slackens to a trickle, but while this trickle exists the press is left under pressure. When the trickle or drainage period is complete, the control cock is again turned and the press commences to drop.

Another operator now commences to remove the cakes with the aid of a long steel rod fitted with a short, flat blade. This tool is known as a " slice." The next step is the removal of the press cloth which exposes a well formed cake with dark, oily edges. The moulder or press filler then commences to replace the pressed cakes with freshly moulded meal in the same manner as that already described, and the cycle commences over again.

Further details of the crushing cycle can only be related to the treatment of particular seeds. An idea of the timing of the successive features of the cycle can be gained from the recording of a typical operation :

Press commenced to drop or open, to fully open	2 minutes.
Fully open, to commenced to close	3½ „
Commenced to close, to just closed	1½ „
Just closed, to full low pressure	2 „
Full low pressure, to change to high pressure ...	1 „
Change to high pressure, to full high pressure ...	2 „
Full high pressure, to opening of press	18 „
Total ...	30 „

The last period of 18 minutes represents the draining period.

To obtain the cycle above, the control box requires certain adjustments which will be described in a later chapter dealing with control box operation and mechanism.

It is now necessary to return to the point when the cakes have been removed from the press and stripped of press cloth. The dark coloured oily edges are trimmed off by means of a paring machine, which may be semi-manual or fully automatic in its operation. The oily edges are re-processed with the new feed of meal and the pared cakes are now ready for nutting or reducing to cake meal for the compound mill.

It is important to note that although the maximum pressure applied to the ram of the press is two tons per square inch; this does not mean that the pressure applied to the cake surface is also two tons per square inch, as the cake area is greater than the area of the ram. The pressure on the cake can be shown thus :

Total pressure on ram, 402 tons.

Area of cake, 34 inches × 13 inches = 442 square inches.

Pressure per square inch on cake therefore

$$= \frac{402 \text{ tons}}{442} \times 2{,}240 = 2{,}037 \text{ lb., or } 0.9095 \text{ tons.}$$

Capacity of the Hydraulic Press

Accurate statements of production capacity could only be given for specific materials and for particular methods of working. The timing table already given related to the crushing of palm kernels. Accordingly, it is advisable that we confine ourselves to palm kernels when dealing with our first attempt at finding the crushing capacity of one press.

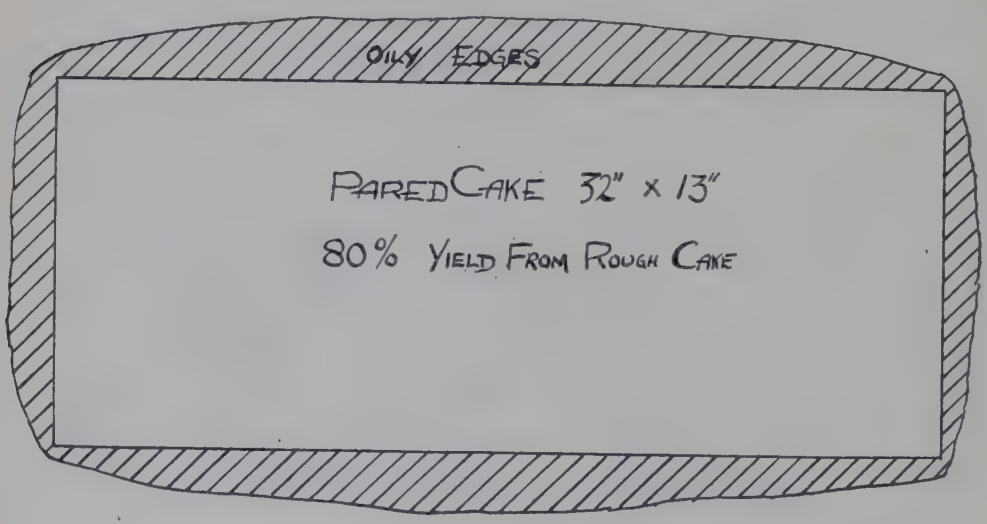


Fig. 39. Press Cake showing oily edges

When this has been found, it is a comparatively simple step to find the capacity of a battery of presses for a given period. The A.-A. press will work palm kernels best when using 15 plates per press. That is to say, there are 15 spaces providing accommodation for one cake to each space. There are certain reasons why this particular plate arrangement is necessary.

Palm kernels, when under pressure, can be compressed to an extent that would cause the plate runners to touch before the maximum pressure was obtained if a thinner cake of the 19 plate type were crushed. Fewer and thicker cakes tend to offset this fault and, therefore, while cottonseed can be worked satisfactorily on a 19 cake press, the ideal for palm kernels is 15.

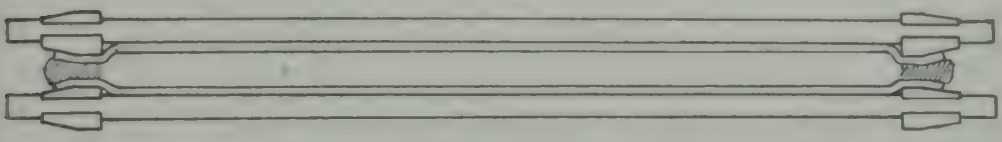


Fig. 40. Section of two press plates showing cake and press cloth

A cake of the maximum possible size is moulded. This would weigh about 18 lb.

After crushing, the oily edges are pared away, leaving a well shaped cake weighing about 9 lb. and containing eight per cent. oil.

The press capacity will, therefore, be :

15 cakes at 9 lb. each = 135 lb.

Since the raw material contained 49 per cent. oil, and the finished cake 8 per cent. oil, the output per operation would be :

$$\frac{135 \times (100 - 8)}{(100 - 49)} = \frac{135 \times 92}{51} = 244 \text{ lb.}$$

This does not mean that the input to the press is 244 lb., because, as yet, the pared cake has not entered into the calculation. In converting unpared cake into pared cake about 20 per cent. by weight is pared away and returned to the cooker.

The parings contain from 24 to 30 per cent. oil, so that the material entering the cooker is a mixture of fresh palm kernel meal at 49 per cent. oil, plus cake parings at 25 per cent. oil. Since the input of the press is equal to the addition of the three products, and the output is the addition of two products only, the best way to show this would be by the following chart :

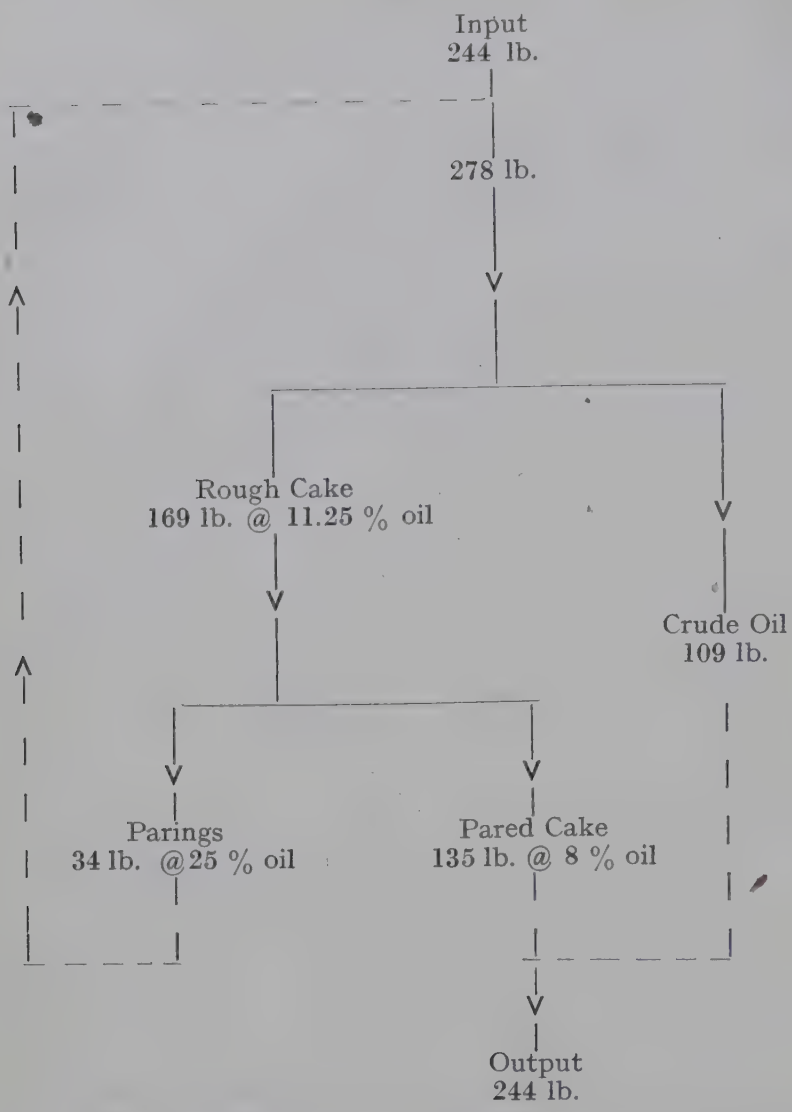


Chart showing progress and quantities involved in the operation of an A.-A. Press

Over a period, the parings cancel themselves out, so that for practical purposes, the input and output balance, except for the moisture behaviour. Since the press under consideration is one of twelve, and each press operates twice per hour for 122 hours per week, the weekly output would be :

Cake at 8 per cent. oil :

$$\frac{135 \text{ lb.} \times 2 \times 122 \times 12}{2{,}240} = 176 \text{ tons.}$$

Oil :

$$\frac{109 \times 2 \times 122 \times 12}{2{,}240} = 142 \text{ tons.}$$

318 tons.

Oil removed in pressing :

$$\frac{142 \times 100}{318} = 44.6 \text{ per cent.}$$

Parings

The parings cannot be returned to the cooker in the form in which they leave the cake, i.e., fairly hard strips and lumps. The new rolled palm meal is soft and fine in texture, and the parings should be reduced sufficiently to enable a proper mixing of these materials to take place. This reduction is obtained by fine gannowing or grinding.

The Parer

There are many types of paring machines in use, some of them automatic and others semi-automatic; the working of a semi-automatic parer is as follows:

The cutting or paring knife is carried by a boss which slides to and fro on a stout steel bar just above the cake table. The reciprocating motion is induced by a long arm attached to the boss, and also to a driving pulley mounted high over the table.

The cake is held in position on the table by the operator, and as the knife moves forward, the obtruding edge of the cake is cut away and falls into a hopper below, where the reducing machine converts the parings into meal. The return to the cooker is obtained by passing the parings meal into a bucket elevator, together with any meal spaded from the press precincts and also with the new material.

Fig. 39 shows a plan view of an unpared cake; the shaded portions being the oily edges. The rectangular central portion after paring is the final cake product.

Fig. 40 shows a section through two press plates. Note how the press cloths are "nipped" by the runners at the ends. Again, the shaded portion shows the oily edges.

A final oil content of 8 per cent. in palm kernel cake is not usually considered the most desirable. In practice, the percentage is often much lower than this.

Control Box, Hydraulic Press

When the press is not in use, the valve (B) (Fig. 41) is tightened down by turning the cock (F). This prevents low pressure oil flowing from the low pressure supply (A) into the cylinder, via pipe (C). To operate the press, the cock (F) is turned anti-clockwise, and in this movement performs two functions.

First, the ball valve (B) is free to rise from its seat by means of the upward thrust of the low pressure oil, i.e. 700 lb. per square inch. Secondly, the shoulder valve (D) is closed against the exhaust outlet.

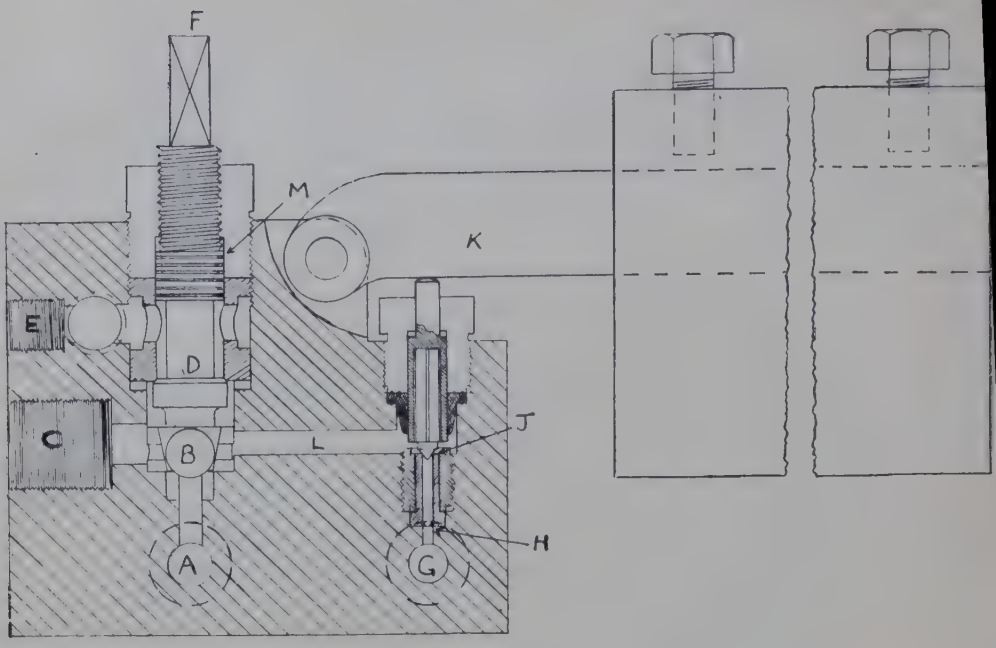


Fig. 41. Hydraulic Press Control Box

Key to diagram :

(A) Inlet pipe low pressure supply.
(B) Inlet valve.
(C) Pipe connexion to hydraulic press.
(D) Valve seating to close exhaust.
(E) Exhaust outlet.
(F) Operational cock for valve control.
(G) High pressure oil supply.
(H) Small bore pathway for high pressure oil flow.
(J) Valve seating closing high pressure supply.
(K) Weighted beam holding high pressure closure valve.
(L) Low pressure connexion to high pressure valve.
(M) Labyrinth seal.

The low pressure oil now flows into the press cylinder and the ram commences to rise. The rate of closure of the press is carefully controlled by the inclusion of a disc in the low pressure pipe line. For slow closing, a disc with a centre hole 3/32nds. of an inch may sometimes be used, though $\frac{1}{8}$ or 7/32nds. of an inch may be satisfactory. Slow closing may be necessary where spreading of the material is at all likely.

When the maximum pressure is reached, the upward thrust on the valve (J) from the high pressure connexion, added to the thrust exerted on the valve shoulder by low pressure, oil via the pathway (L), is sufficient to raise the valve (J) off its seat. High pressure oil immediately flows into the pathway (L), and since this supply is at two tons per square inch, the ball valve (B) is pushed hard down, the upward low pressure thrust being quite inadequate to resist the greater downward thrust. This effectively closes the low pressure supply, and the press cylinder

now receives oil at two tons per square inch. The total travel of the press ram tends to vary with the particular material being processed. An approximate distance is, say, 2 ft. 6 ins.

The effect of the change-over from low pressure to high pressure supply results in a further travel of about 4 ins. before the ram becomes stationary. By now, the oil is gushing from the press, and after the main gush has finished, a steady drain takes place for about 15 to 20 minutes.

When the draining has ceased, the press is dropped which, in oil mill parlance, means "opened up" for the removal of pressed cakes and insertion of new material for the next crush. To open the press, the operator turns the cock (F) clockwise and the operation described at the beginning repeats itself. The ball valve is held hard down and the shoulder valve opened to exhaust. The drop in pressure, due to the opening of the exhaust, causes the weighted valve (J) once more to fall into place, thus sealing off the high pressure inlet.

The screwed-in fittings are seated on copper washers which assist in bedding them down neatly and so avoid leakage. The labyrinth seal (M) immediately below the threaded portion of the cock assists in preventing exhaust oil from passing out through the top of the box. The name "labyrinth" will be, to some students, self explanatory, a series of grooves are turned on the stem of the valve; these grooves become miniature oil chambers which slowly fill up with oil as succeeding obtruding rings are passed.

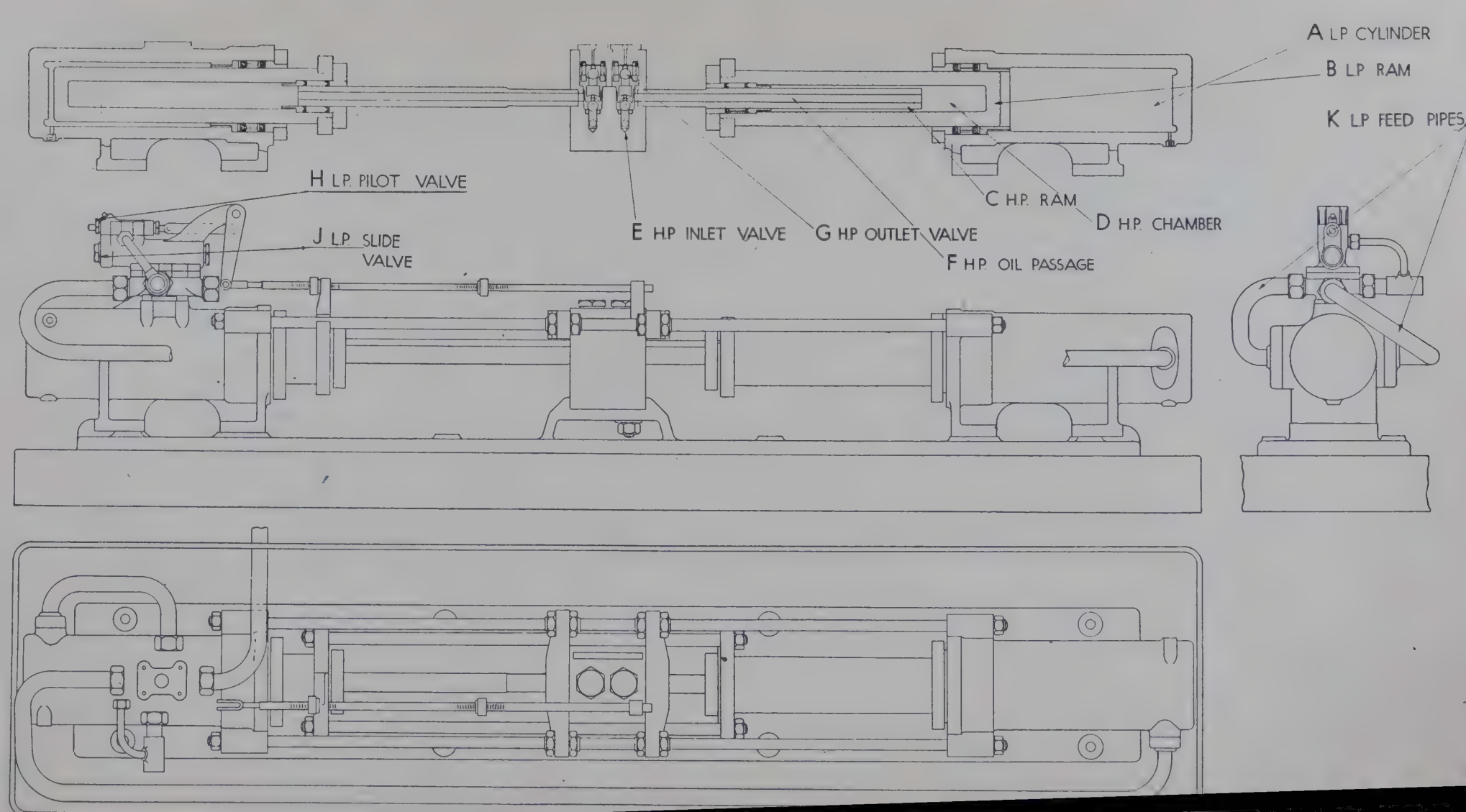
The leaking oil, which is inevitable on a face-to-face joint, eventually finds its way to the outside if the flow is of a permanent nature but, of course, this in practice is not the case.

Oil can only flow into the labyrinth when the exhaust valve is open and the press is dropping. When oil no longer flows to exhaust, it no longer flows into the labyrinth. The correct position of the weight on the counter weight arm can be found by trial and when the position has been found, the securing bolts are screwed hard down to prevent its moving. The operator sometimes finds that the press will not take high pressure properly on occasion. When this happens, it will be found that the weight has slipped forward slightly due to the consequent sudden drop of the high pressure valve when the press is opened to exhaust. The remedy lies in resetting and securing the weight.

CHAPTER XIV.

THE OIL MILL INTENSIFIER

The intensifier is, in reality, a hydraulically operated pump, the purpose of which is the production of a volume of oil at very high pressure. The chapter on hydraulic plant indicated


A L.P CYLINDER
B L.P RAM
K L.P FEED PIPES
H L.P. PILOT VALVE
J L.P. SLIDE VALVE
E H.P INLET VALVE
G H.P OUTLET VALVE
F H.P. OIL PASSAGE
C H.P. RAM
D H.P. CHAMBER

at seed crushers make use of two separate intensities of ressure for the operation of the hydraulic press.

The first, known as low pressure, does not exceed 700 lb. per quare inch, while the second, or high pressure, is two tons per quare inch. In some cases, both low and high pressure is btained by means of reciprocating pumps operated by means of crank shaft. In other cases, however, the low pressure only obtained by direct pumping, high pressure must be obtained y the use of the intensifier.

Description of Machine

The sectional elevation (Fig. 42) shows the general rrangement without the control mechanism. Two low pressure ams (B) perform an alternate movement in the low pressure ylinders (A). The movement is caused by alternately filling the ylinder (A) with oil from the low pressure system, i.e., 700 lb. per square inch.

Two high pressure rams are projected immovably from he high pressure valve box housing the valves (E) and (G). When low pressure oil flows into the right hand low pressure ylinders, the left hand low pressure cylinder is opened to xhaust by means of the control mechanism which will be lescribed later. The low pressure ram, or piston, also acts as a ylinder for housing the high pressure ram. The high pressure am (C) does not move, the cylinder itself providing the move- nent. As the left hand low pressure ram moves back from its troke, the volume inside the left hand high pressure cylinder ncreases, resulting in a sudden drop in pressure within the high pressure cylinder.

The oil in the gravity feed inlet pipe to the high pressure nlet valve (E) is at atmospheric pressure, plus the head from he supply tank. This is sufficient to force the valve (E) up rom its seat, and oil flows into the high pressure cylinder. When the stroke has reached its limit, the control mechanism mmediately switches the low pressure supply back to the left and low pressure cylinder which now moves forward.

The forward action of the left hand low pressure ram causes reduction in volume inside the high pressure cylinder on the eft side, the back pressure from which immediately closes the igh pressure inlet (E) and opens the outlet valve (C) also on he left hand side. The valve will only open when the pressure nside the cylinder is greater than that already in the high pressure system.

On completion of the stroke, the control mechanism auto- atically switches the low pressure supply back to the right hand ylinder, and the cycle is again repeated. The machine works at 0 to 12 complete strokes per minute. The amount of low ressure oil consumed as well as the amount of high pressure oil

produced can be readily calculated and the resultant high pr sure can be determined in a similar manner.

Diameter of low pressure cylinder 6 inches, stroke of l pressure ram 1 foot 6 inches.

If oil from the low pressure system exerts a pressure of 7 lb. per square inch on the low pressure ram, the total force o posed on the low pressure ram face is :

$$\frac{22}{7} \times 3 \times 3 \times 700$$

$$= 28.29 \text{ square inch} \times 700$$

$$= 19{,}800 \text{ lb.}$$

A total force, therefore, of 19,800 lb. pushes against t opposing high pressure ram, the diameter of which is tw inches. The area of the high pressure ram =

$$\frac{22}{7} \times 1 \times 1 = 3\ 1/7 \text{ square inch}$$

If the total force of 19,800 lb. is exerted against 3 1/7 squa inch, the pressure per square inch set up in the high pressu cylinder =

$$\frac{19{,}800}{3\ 1/7} = 6{,}300 \text{ lb. per square inch}$$

In practice, the high pressure cylinder cannot attain th possible maximum owing to the accumulator set in the syste which is weighted to rise at a pressure of 4,480 lb. per squar inch. The presence of the accumulator guarantees that at n time can the pressure in the system exceed that amount necessar to float its weights. Should the volume of high pressure o exceed the demand, the accumulators would further rise until, o reaching the safe limit of travel, a relief valve is automaticall operated.

Hourly consumption of low pressure oil =
Volume per stroke (in ft.) × lb. per cu. ft. × no. of stroke

$$\frac{28.23 \times 18}{1{,}728} \times \frac{(56)}{(1)} \times \frac{20 \times 60}{2{,}240}$$

$$= 8.82 \text{ tons of low pressure oil per hour}$$

Production of high pressure oil =

$$\frac{8.82 \times d^2}{D^2} = \frac{8.82 \times 2 \times 2}{6 \times 6} = 0.99 \text{ tons per hour}$$

Control Unit for Oil Mill Intensifier

The inlet feed of oil destined to provide the high pressure supply is, of course, gravitational, plus the added impetus given by the creation of a partial vacuum when the volume of the high pressure cylinder is increasing.

The actions described can only take place, however, when co-ordinated by means of a complete piece of mechanism, known as the slide valve, is in operation. The slide valve is also controlled by means of a pilot valve.

The pilot valve operation is alternately hydraulic and mechanical, while the slide valve is operated entirely by hydraulic pressure. The hydraulic agent, or source of power, is the low pressure supply line operating at 700 lb. per square inch.

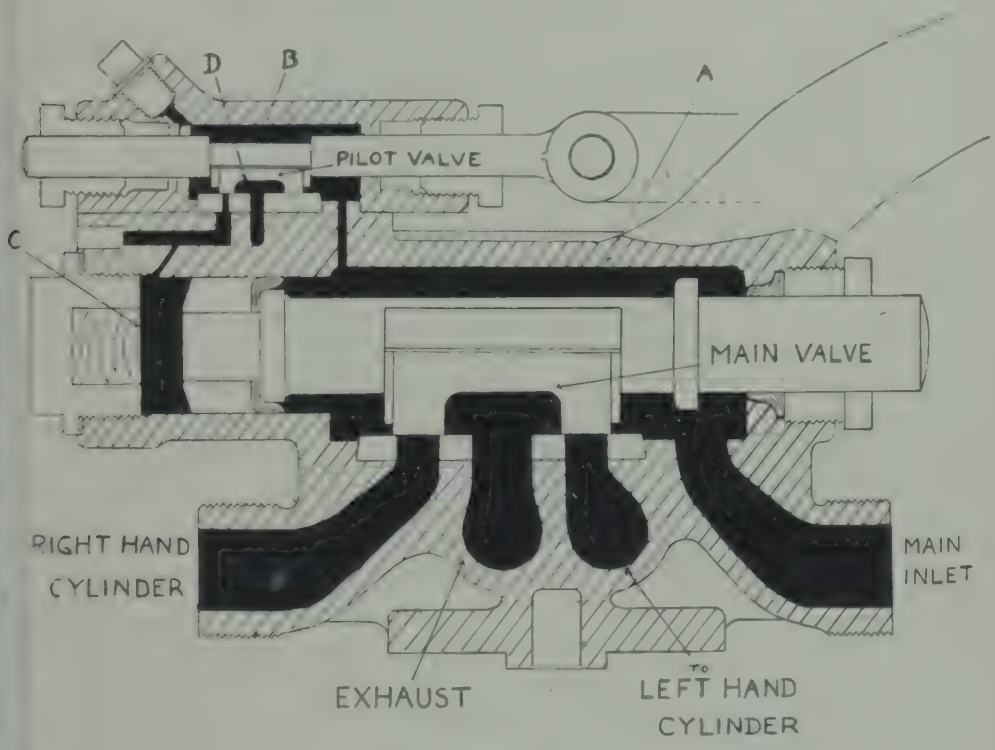


Fig. 43. Intensifier Control Unit

The illustration (Fig. 43) shows a sectional elevation of the control unit of an Intensifier. The arm sloping out on the right carries the rod which draws the pilot valve forward on the forward stroke of the left hand low pressure ram. The The blacked out chambers and ducts indicate the progress and movement of the low pressure oil.

The pilot valve is moved forward mechanically in the manner reviously described, and the movement of this valve operates ie main slide valve by hydraulic pressure.

Oil enters the main inlet, floods the slide valve chamber (A), nd by means of the vertical duct, floods also the pilot valve oil

chamber (B). The low pressure, acting on the flanges of t main valve shaft, forces the shaft to the left in a forward stro This movement affects both low pressure cylinders immediate The central exhaust chamber and the right hand cylinder pi are connected, and oil flows from the right hand cylinder pi to exhaust. At the same time, the left hand low pressu cylinder pipe is connected to the slide valve oil chamber (A), a the left hand low pressure ram commences to move forwar The forward movement of the left hand ram coincides with t backward movement of the right hand low pressure ram whi is, of course, opened to exhaust.

When the forward stroke of the left hand ram is nearin completion, the pilot valve is drawn forward also, and the lo pressure oil flows via three narrow ducts into the chamber the head of the main slide shaft (C) on the left.

The pressure per square inch is the same in both the ma chambers (A) and the small chamber (C), but the area at th head of the shaft is a complete circle, while the area acted upo in the main valve chamber is merely an annulus, the shaft forn ing a blank in the centre.

The pressure in the valve head chamber (C) can therefor exert a much greater force than that in the (A) portion, and th valve is forced to travel forward to the right.

The right stroke of the valve shaft now connects the righ hand cylinder with the low pressure oil flow, via the chambe (A), causing it again to move forward. At the same time, th left hand cylinder is now opened to exhaust. This causes a immediate change in the direction of the stroke, and the cycl completes itself and starts again.

When the pilot valve moves to left on the backward stroke of the left hand low pressure ram, the slide valve head chambe (C) is opened to the pilot valve exhaust pipe (D), and once mor the right hand low pressure cylinder moves to the left to exhaus the right hand low pressure cylinder which has just complete a forward stroke, and, of course, to allow the low pressure oi to flow into the left hand cylinder once more. The two exhaus chambers between the slide valves are not connected to the mai chambers (A) and (B), but only to the ducts or pipes from th low pressure cylinders and the main valve head chamber (C).

CHAPTER XV.

THE HYDRAULIC ACCUMULATOR

It is essential that the pressure oil available should be a constant pressure. Since the consumption or rate of usage o pressure oil is variable, the rate of production of pressure oi

must vary likewise. To obtain this condition, a system of balance must be arranged which, by its linkage in the main

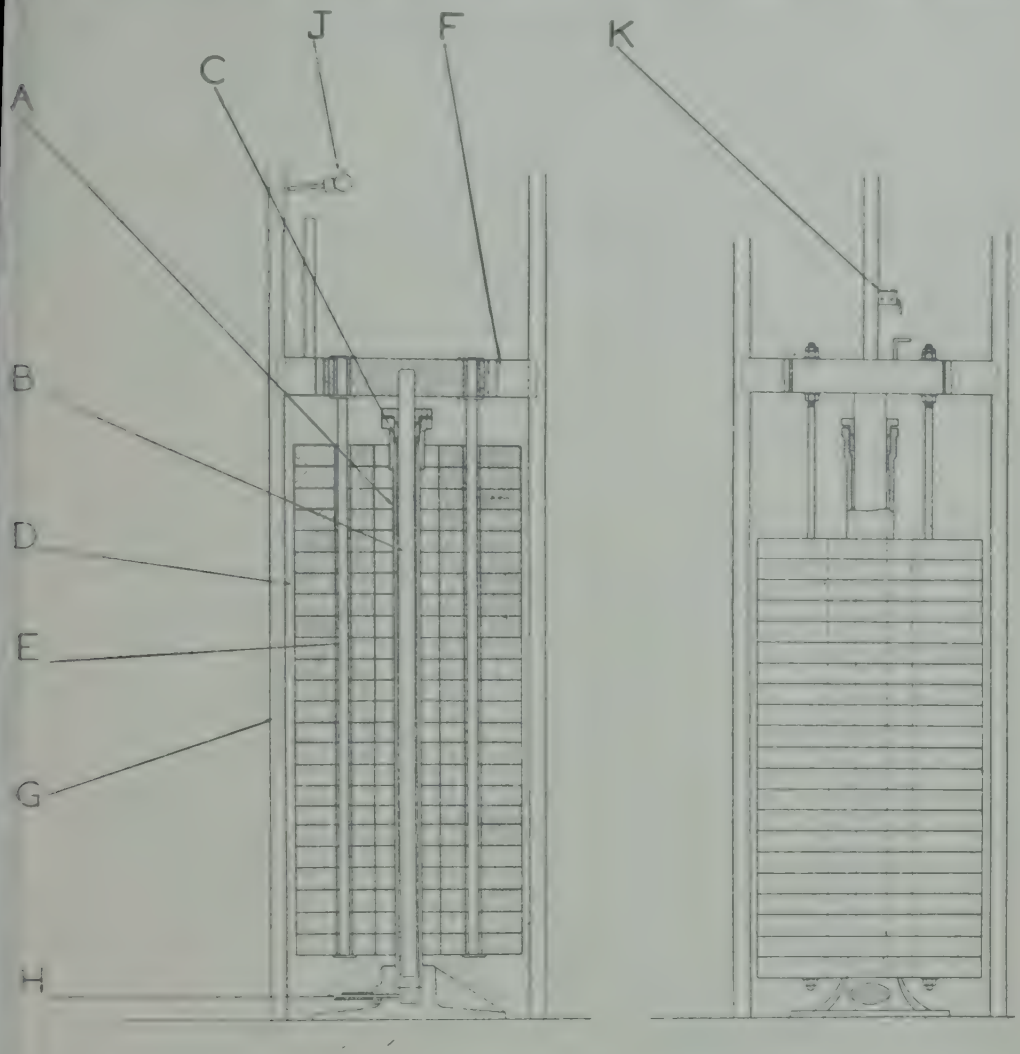


Fig. 44. Accumulators in Section

A	Cylinder	F	Sling Bolt Support
B	Ram	G	Channel Runners
C	"U" Leathers	H	Oil Inlet Pipe
D	Balance Weights	J	Escape Safety Valve
E	Sling Bolts	K	Circuit Breaker Pumps

system, will store a small volume of oil and, at the same time, lower the pressure oil production should the consumption rate be temporarily reduced. The answer to this is the accumulator.

The low pressure accumulator (Fig. 44) is shown with the ram and casing partly in section.

The ram (B) is 6 inch diameter, floating at the bottom and firmly fixed at the head in the sling bolt support (F). The cylinder (A) is bolted to the ground by its base casting which affords an inlet for the low pressure oil, marked (H) on drawing. The sling bolt support is held loosely at the ends by

means of the channel runners (G). The balance weight (I is composed of a series of large iron discs carried by th sling bolts (E). Leakage of oil at the top is prevented by th insertion of a " U " leather (C), and above this, a hat leathe The top cover above the hat leather is bolted firmly to th cylinder top. The bolts are not shown in the drawing, sinc they are on either side of the casting.

Slung from the support (F) are 21 discs weighing approxi mately one-third ton each. The total weight of the discs, plu the ram and support, is 8.84 tons. The pressure in th cylinder when the weight is floating is, therefore :

$$\frac{\text{total weight}}{\text{area of ram}} = \frac{TW \times 2{,}240}{\pi r^2} = \frac{8.84 \times 2{,}240}{3.142 \times 3 \times 3}$$

$$= 700 \text{ lb. per square inch.}$$

The pressure of the hydraulic medium, in this case 700 lb. per square inch, is constant while the accumulator is floating. When at rest, the weight of the accumulator stands on four hardwood blocks. When the supply of pressure oil exceeds the demand, the accumulator continues to rise. This rise must not exceed a safe limit and a means of imposing a limit is incorporated with the general system. The particular means of obtaining an upward limit depends upon the type of pump in use, but generally, a release valve (J) is operated and surplus oil allowed to run to exhaust. Should the release valve prove insufficient and the accumulator continue to rise, the electric circuit is broken by the upward movement and the pumps stopped. The circuit breaker is marked (K).

Should the pressure oil exhaust too rapidly owing to excessive demand from the presses, the shock of such a large weight dropping on to its wooden support points would be very

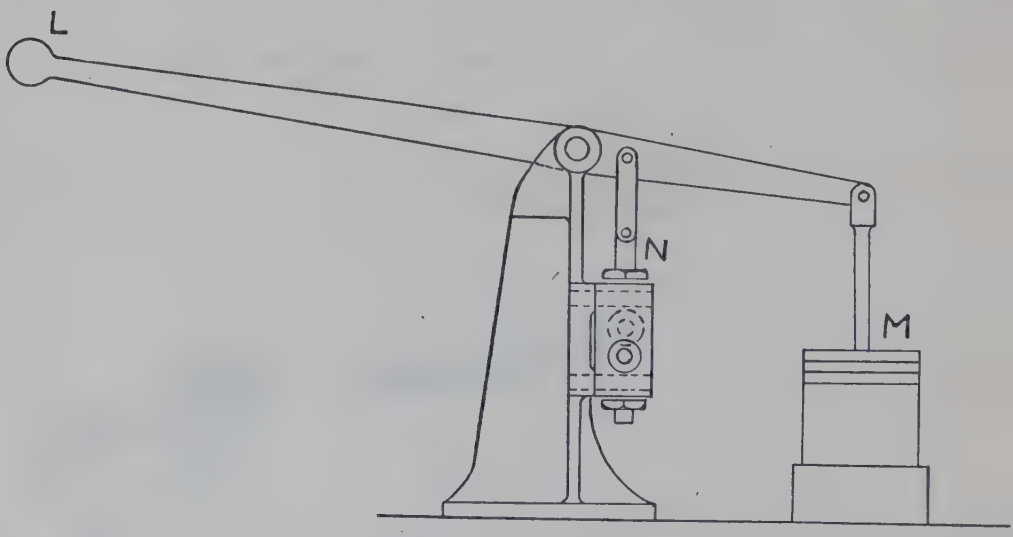


Fig. 45. Single Acting Control Valve

severe. The dropping shock is minimised by the inclusion of a control valve on the inlet/outlet oil pipe line.

Single Acting Control Valve

Fig. 45 shows valve box and control lever when the accumulator is floating. When the accumulator is at rest the lever is held firmly down at the point (L) by means of an obtruding nib fixed to one of the lower weight discs. The valve spindle (N) is therefore raised to its highest point, causing the main pressure oil inlet to be seriously restricted.

When pressure oil first flows into the valve box by means of the pathway (O), the ball valve (P) is lifted and the oil flows past to top valve shoulder to the outlet pipe (Q) and into the accumulator cylinder. The flow causes the accumulator to rise from its base resulting in a change in position of the control lever.

The end (L) rises, due to the downward pull of the counter weight (M) and the removal of the depressing nib on the side of the accumulator. The valve spindle (N) slowly moves downward with the weight (M) and when the weight comes to

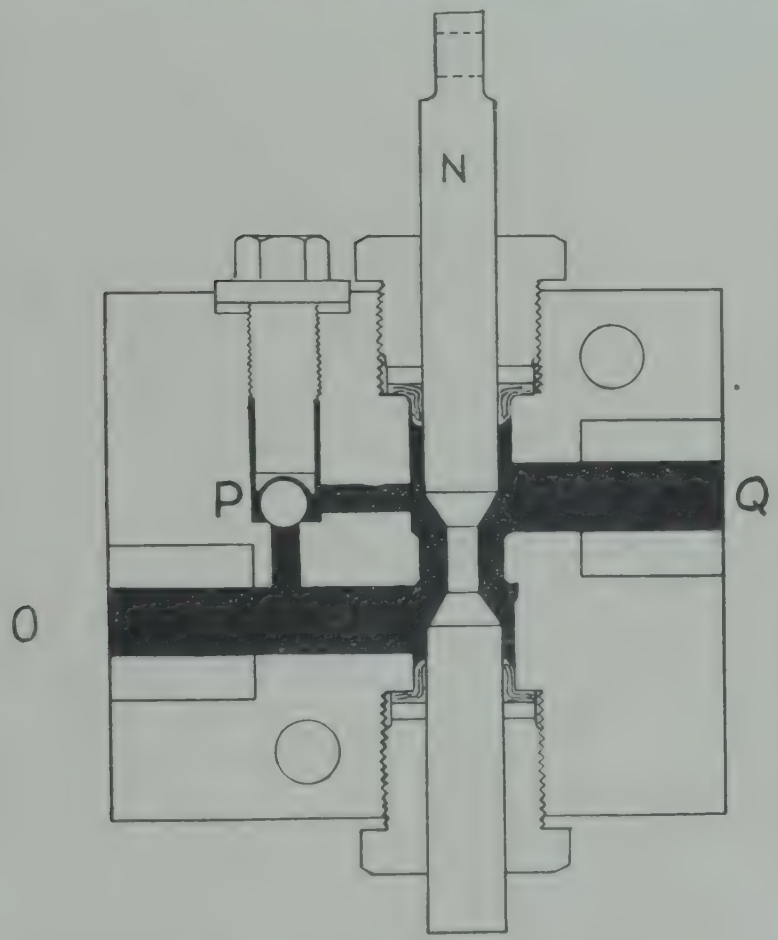


Fig. 46. Section of Control Valve Box

rest, the lower shoulder of the valve spindle is removed from the main oil flow pathway so the flow switches from the ball valve line to the main pipe and the ball valve falls back into position. The main flow pathway continues to feed the cylinder of the accumulator until the demand rate for pressure oil exceeds the supply. When this happens, the flow of oil reverses direction and the accumulator commences to drop. The rapid drop may continue until the base of the accumulator is within a few inches of the rest position. At this point, the obtruding nib strikes the lever once more. Immediately the valve spindle is raised and the main feed pipe flow which, of course, is away from the accumulator, suffers a severe check. This is because the lower shoulder on the valve spindle has once more risen to a position which almost closes the vertical chamber between the ducts (O) and (Q) (Fig. 46).

The accumulator weight is now resting on the wood block, this condition will remain until the pressure oil supply increases sufficiently to induce it to rise once more.

The high pressure accumulator acts in a manner similar to the low pressure described above. The cylinder ram in this case is 3 inch diameter and weighted to support a pressure of two tons per square inch.

PART II

COMPOUND & PROVENDER MILLING

by

A. S. MOORE, A.M.I.Mech.E.

CHAPTER I.

INTRODUCTION

In the prospectus covering the evening class sessions, th course was given the double-barrelled title of "Compoun and Provender Milling." There seems to be a certain amount o confusion regarding the meaning of these terms; some peopl use "Provender Milling" as a term covering the whole of th combined industry, while others use the term "Compoun Milling" as the comprehensive term. The fact is, of course, tha compound milling and provender milling are each in themselve separate and distinct industries in their own right. They are th progeny of the oil seed crushing industry and the flour millin industry respectively.

Compound Milling

At this point, it may be convenient to attempt to define approximately just what is meant by these terms. Firstly, compound milling may be considered as the bringing together of edible substances, in a mixture, in such proportions as will constitute a balanced diet, or a special diet, for livestock.

The term compound is misleading to some extent, in that a compound means a chemical combination of substances not separable by mechanical means, whereas, in fact, each of the ingredients in a compound food retains its identity and the product is, therefore, more accurately called a mixture. The term compound has, however, been established by custom and is useful in that it does suggest intimacy of mixing.

Provender Milling

Provender milling is the process of preparing substances of a cereal or leguminous character for the feeding of livestock, and is mainly confined to the production of single ingredient feeds, *i.e.*, maize meal, barley meal, crushed oats. These definitions, however, are not precise, and we find compound mills producing maize meal and provender mills producing compound meals. Again, in the compound mill, it is necessary to produce the finished products of the provender mill as raw materials for the compound process. Nevertheless, for the purposes of these lectures, it is considered advisable to use the definitions so far given and for a comprehensive term to cover the whole industry, "The Manufacture of Feeding Stuffs for Livestock," or for short, "The Feeding Stuffs Industry" could be employed.

Industrial Processes

In the consideration of any industry, it is convenient to look upon it as a collection of a number of separate or unit processes or operations, such as: materials' handling, grinding, drying, cooling, humidifying, extraction, extrusion, mixing, filtration, screening, classification, etc. Compound milling, for instance, might be shown to be composed of materials' handling, grinding, mixing, cooking, cubing, cooling and screening or size separation. This list is not strictly one of basic unit processes; cooking, for instance, is really a combination of heat transfer and humidification, but at this stage, it is perhaps advisable to keep to the ideas with which we are reasonably familiar.

From this point of view, it will be seen that many industries, although having apparently nothing in common, are in fact composed of different arrangements of the same unit processes adapted to handle different materials. In their process of manufacture, paint, gunpowder and dairy meal have all been subjected to grinding and mixing, and the fundamental considerations underlying the grinding and mixing are the same for paint and gunpowder as for dairy meal. This, of course, does not mean that the paint mixer is the same machine as the meal mixer, or that gunpowder is ground like coconut cake, but it does mean that if the fundamental principles of mixing and grinding are understood, it is but a short step to their proper application to any mixing or grinding problem.

The Three Basic Laws

Students may well observe, in view of the foregoing, that they are not particularly concerned with *any* grinding problem, but only with those arising in the manufacture of feeding stuffs. The truth of this observation would have to be admitted, but the conception of industry as indicated is useful in that it does indicate a relationship between our own industry and industry in general; it also shows that the most complicated industrial processes can be split up into simpler unit operations which are governed by a few basic laws.

These laws may be grouped as follows:

(1) The laws which say that neither matter nor energy can be created or destroyed.

(2) The laws governing the changes that take place in a process.

(3) The laws governing the rate at which these changes take place.

Whilst these laws may sound somewhat formidable, and whilst in special circumstances their application may be very complicated, students will be familiar with a hundred and one examples of the functioning of the laws.

The first law, for instance, says that matter cannot be destroyed. Matter is any substance that exists and may be found in one or all of three familiar states: solid, liquid, gaseous.

It should be noted that whilst we cannot destroy matter, it possible and sometimes easy to change its state. For instanc a pound of water can be frozen into a pound of ice or boiled in a pound of steam, *i.e.*, its state can easily be changed from liquid to a solid or to a gas. The important point to be remem bered is that, having started with a pound of water, we ar bound to continue with the pound of matter whether we chang it into a solid or into a gas. If we go a step further and split th water into its two components, hydrogen and oxygen, th combined weight of these two gases will still be one pound When coal is burned, the matter certainly no longer exists a coal, but if the products of the combustion were collected, *i.e.* the ash, and the smoke or gases given off, it would be found tha their combined weight would be equal to the original weight o the coal, plus the weight of the air used up in the burning o the coal.

If half a cwt. of material is lost in grinding one ton of oats, it does not mean that this half cwt. has gone out of existence, though this would certainly appear to be the case. Nevertheless, if the necessary care was taken, it would be possible to account for every ounce of this loss. Some of the loss may have gone in fine dust or water vapour, while some of the meal may have become lodged in the grinding or conveying machinery, but these losses can still be accounted for. This principle can and should be applied over the whole of the mill process, and a balance sheet drawn up upon which unaccountable losses should be insignificant.

The practical significance of this law is that whatever material is fed into a process can be accounted for, providing the necessary measuring equipment is available.

The second law, which deals with changes in a process, says that there will be a movement or change in any system which is not in equilibrium or balance. For instance, heat will continue to flow from one end of a hot poker to the other end until the temperature is the same at both ends. The unbalance which caused the flow was the difference in temperature between the cold end and the hot end of the poker. Steam will flow along a pipe because the pressure at one end of the pipe is higher than the pressure at the other end, *i.e.*, it is out of balance.

The third law governs the rate at which the changes take place, or the system becomes balanced, and takes note of such things as thermal conductivity or heat transmitting power of materials, viscosity or reluctance to flow of materials, and all the other factors with which we need not at present concern ourselves, but which affect the rate at which a system attempts to balance itself.

The latter two groups of laws may be called the laws concerning equilibrium. It is the application of these laws which,

for instance, indicates the quantity of molasses that will flow along a certain size of pipe under certain conditions of temperature, and pressure unbalance (which in dealing with the flow of fluids is called "head").

All the laws covered by these groups are capable of varying degrees of mathematical expression, and although their mathematical form is principally the concern of the plant designer, students should always remember that there are laws which govern the behaviour of machines and materials. If a machine behaves differently today from what it did yesterday, it is not mere caprice. A meal which flowed down a chute on one day and refuses to budge on the next does not imply a "hangover"; there is a logical explanation for such behaviour.

In forthcoming chapters, there will be few occasions for referring to these laws, but our examination of many machines and processes will be made all the easier if what may be called the law abiding character of these machines and processes is remembered.

One of the most striking characteristics of compound milling plant is the remarkable range of machines that have been designed to do the same job. Practically all the designs have an empirical basis and have been developed on the principle of trial and error. This is not a condemnation, far from it, but when a wide range of machines is offered for the same job, it is not unreasonable to suspect that the laws governing the work which the machine is designed to do are not completely known.

In examining individual machines, it will be necessary to decide how far they meet the purpose for which they were designed. To do this, it will be necessary clearly to have an accurate picture of what that purpose is. Machines are often condemned for their inability to do work for which they were not designed.

Purpose of Machines

The purpose of machines in general is to do work. Work is always done upon something; therefore, to determine the the purpose of any machine, consideration must be given to:

(a) The performing of an operation;

(b) The object upon which the operation is effected.

For the consideration of most feeding stuffs machinery, this may be expressed as "knowing the nature of the materials to be fed to a machine and the operation the machine must perform on them."

The list of operations in compound milling is comparatively small when considered against the list of possible raw materials.

Raw Material Problems

During and immediately after the 1939-45 war, the list of materials commonly used in any quantity was very different from what it was before the war. The most outstanding characteristic of this change was the substitution of a large proportion of common cereals for the oil seed residues, locust beans and rice meal which formed the greater part of the pre-war mixings.

The effect of this change was most marked, and on many occasions it gave the compound miller a bad headache, because, unlike the provender mill, the compound mill was not designed to handle a high proportion of cereals and the plant quickly showed its resentment.

For instance, a modern pulverizer which had before the war devoured ten tons per hour of groundnut cake refused to have anything to do with more than one ton of oats, and at that spewed out large volumes of steam and porridge. Cubing machines stuttered when fed with coarse, fibrous meals instead of the smooth, oily feeds to which they had been accustomed. Even the bags into which the finished products were packed refused to accommodate their usual quota.

Material Characteristics

This indicates that it is of some importance to know the characteristics of the materials which are used in the mill, at least with those characteristics which are likely to affect the working of the plant. These can be listed as follows :

DENSITY : The weight of unit volume. For instance, a gallon bucket when full will hold 5 lb. of groundnut flakes and it could therefore be said that the density of ground nut flakes is 5 lb. per gallon. It is usual, however, to express density as the weight of a cubic foot, and as there are very roughly $6\frac{1}{4}$ gallons in a cubic foot, the density of ground nut flakes is better expressed as

$$5 \times 6\tfrac{1}{4} = 31\tfrac{1}{4} \text{ lb. per cubic foot.}$$

Density is sometimes expressed as bushel weight, in which case it is the weight of a bushel of the material.

SHAPE : Needs no defining, but it is an important characteristic of materials like the locust beans, expeller flakes and oilseed press cakes.

STICKINESS : Chiefly concerns damp, powdery materials, oily meals and sugar-containing substances like locust. There is no standard measurement, but the degrees of stickiness might be termed very sticky, sticky and not sticky.

PARTICLE SIZE : This is measured by the size of the hole through which the particle will pass and may be expressed as some size in inches, or as passing through a specific British standard screen.

ANGLE OF REPOSE: This is the angle at which the material will just not slide upon itself, and may be determined by allowing the material to fall freely into a heap and measuring the angle which the side of the heap makes with the horizontal.

FRIABILITY: This is a measure of the cohesion between the particles, a very friable material being one which is broken up easily.

MOISTURE CONTENT: The measure of the quantity of free moisture contained by a material and usually expressed as a percentage of the bulk.

For the present, it will be sufficient to become familiar with the appearance, size, shape and weight of the materials, and possibly their origin.

CHAPTER II.

CONSIDERATION OF RAW MATERIALS

The whole of the materials may roughly be divided into six categories, namely:

1. Oil cakes,
2. Cereals,
3. Cereal products,
4. Leguminous seeds,
5. By-products and miscellaneous,
6. Minerals,

Oil Cakes

Oil cakes fall into three main classes: Cakes, flakes, and meal, with a further sub-division of nutted cake, cake meal and extracted meal.

CAKES are made in a variety of shapes and sizes, two common ones being the circular, about 19 inches diameter and $\frac{3}{8}$-inch thick, and the rectangular, about 30 inches by 10 inches by $\frac{3}{8}$-inch thick. Certain Manchurian cakes are circular, having a thickness of three inches and over.

NUTTED CAKE: The product obtained from the kibbling of the above cakes and consists of mixed lumps of an average size of $\frac{5}{8}$-inch cube.

CAKE MEAL: Here the cake is ground into a comparatively fine meal.

EXPELLER FLAKES vary in size from pieces $\frac{1}{2}$-inch square and $\frac{1}{4}$-inch thick to irregular shaped pieces measuring three and four inches across and with thicknesses up to $\frac{1}{2}$-inch. A common feature of flakes is the curve of the two large faces, which are also shiny. This material may be received in the ground condition.

Extracted Meal

This is a dry, gritty meal when properly treated, but may be received in a damp condition.

These oilseed products are made from a number of different kinds of seeds. The process of production varies in some degree for each of these seeds, but the main principles are as follows :

The seeds are first cleaned and decorticated if necessary; with cottonseed, delinting may be needed. After cleaning, their

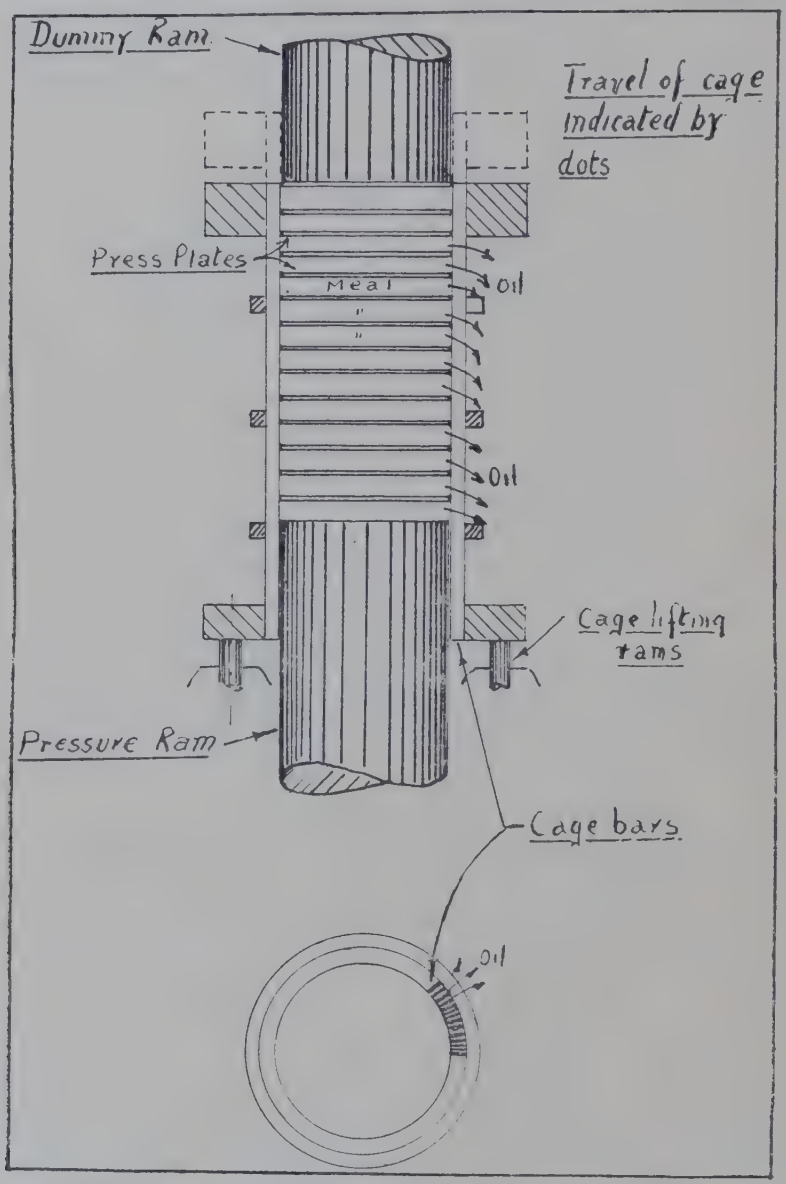


Fig. 47. Cage Press

size is reduced by passing through sets of fluted rolls, after which the granules of seed are passed between smooth rolls which produce a flaky product for feeding to the cooking kettles. The cooking with steam prepares the seed for yielding its oil content either by :

(a) hydraulic pressure in cage or plate presses which yield the round and rectangular cakes respectively, or

(b) by mechanical pressure as in expellers, or

(c) by the action of a solvent as in the extraction process.

In the cage press (Fig. 47) the meal is fed into a vertical cylinder formed of vertical bars of steel spaced at regular small intervals. The meal is fed in charges sufficient to make one cake,

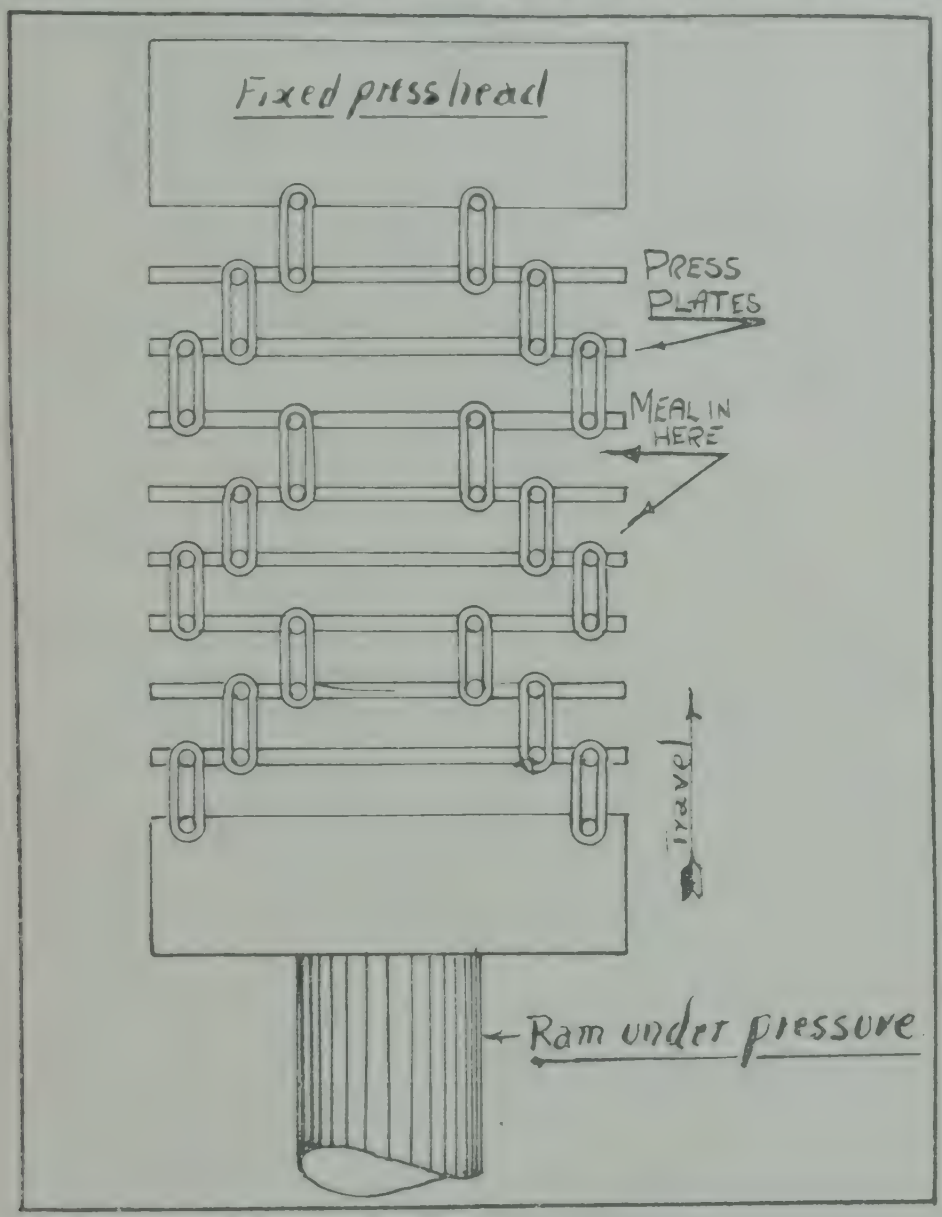


Fig. 48. Plate Press

and after each charge a circular steel plate just smaller than the cylinder and about 5/16-inch thick is placed on top of the meal; the filling process continues, alternate meal and plate, until the cylinder is full. The bottom of the cylinder is closed by a hydraulic ram, and when the press is full, another short ram, known as a dummy ram, is swung over the top of the cylinder which is closed thereby.

Hydraulic pressure reaching two tons per square inch is applied to the bottom ram, which travels up the cylinder compressing the meal causing the oil to flow away through the spaces between the cage bars. After a predetermined time, the top of the cylinder is opened by the removal of the dummy ram and the meal now compressed to cake form is ejected from the top of the cylinder. These cakes contain an average of between 5 and 10 per cent. of oil, depending upon several factors, one of which is the particular seed being crushed.

The plate press (Fig. 48) consists of a number of rectangular steel plates suspended one from another in such a manner as to permit the plates to approach each other under the action of the hydraulic ram over which they are situated. The meal, having previously been formed to a rectangular shape in a cake moulding machine, is wrapped in a cloth and fed into the spaces between the press plates. When the press is full the ram rises, expresses the oil, and is finally lowered leaving between the plates firm cakes containing about 10 per cent. of oil.

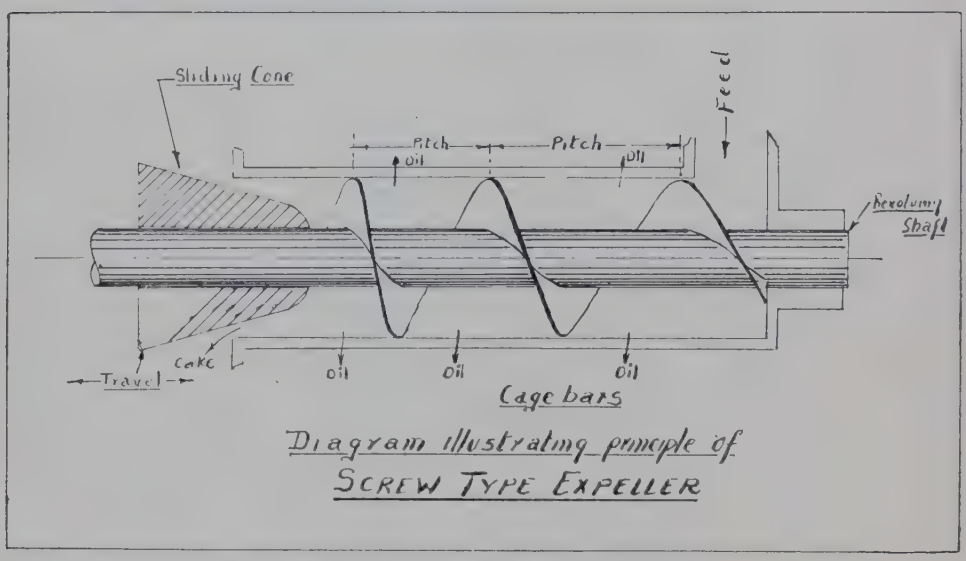


Fig. 49. Screw Type Expeller

Upon being taken out of the press the rich oil bearing edges of the cakes are trimmed off and returned for further pressing.

The expeller which has been most successfully developed is the screw type (Fig. 49), in which a screw, or worm, with a reducing pitch conveys the oilseed through a cage, usually consisting of bars with small clearances between each and through which the expelled oil escapes. The pressure is obtained by the reducing pitch of the worm compressing the meal into a continually lessening volume and is aided by an adjustable cone at the outlet end of the cage.

There are a multitude of different designs of extraction plants, but the essential feature of the process is the washing of

the meal with solvent until practically completely degreased. The residual meal is then steamed until there is no trace of solvent remaining in it, after which the meal is dried, cooled and bagged.

Oilseed Residues

The more important of oil seeds are palm kernels, coconut (or copra), ground nut, linseed, soya bean, cottonseed, rapeseed, sesame and sunflower, the residues from which are:

PALM KERNEL CAKE: Pale fawny-grey, speckled with dark brown; hard, flaky construction. Shape varies with type of press in which produced. The ground meal weighs about 28 lb. per cubic foot. Slightly acrid smell.

PALM KERNEL MEAL EXTRACTED: Not dissimilar in colour to the cake, but of a very much lighter tone. Granular product with conspicuous specks of dark brown skin. Weight, 12½ lb. per cubic foot.

COPRA OR COCONUT CAKE: Greyish-brown colour, varies to distinctly fawn; not as hard as palm kernel cake. Distinctive, pleasant smell. Meal weighs about 29 lb. per cubic foot. Extracted meal, fawny colour. Weight 12-14 lb. per cubic foot.

GROUND NUT: Usually expeller curves. Brown lumps or ⅜-inch thick flakes with two slightly curved polished surfaces. When kibbled, the curves average 36 lb. per cubic foot; when ground, the meal weighs 38 lb. per cubic foot.

LINSEED CAKE: Greyish to reddish brown. Meal weighs about 33 lb. per cubic foot.

SOYA BEAN CAKE MEAL: Colour varies with origin of seed, but a large proportion of cake is a greyish colour, and the meal weighs 35 lb. per cubic foot. Extracted meal, light fawn colour, weighs 27 lb. per cubic foot.

COTTONSEED CAKE: Choice grade; bright yellow, sweet smell, soft and friable; meal, deep canary colour. Inferior cakes may be hard and flinty, or off colour. Decorticated cotton cake meal weighs about 37 lb. per cubic foot. Undecorticated cotton meal has a distinctive woolly appearance due to the presence of lint which is more noticeable in the dull, brown Bombay cake.

SESAME (GINGELLY-JINJILLI): Resembles linseed cake in appearance, but of lighter colour and weighs about 30 lb. per cubic foot when ground.

SUNFLOWER: Off-white in colour depending upon variety of seed and has an average weight of meal about 33 lb. per cubic foot.

Cereals

True cereals may be defined as the edible seeds of grain produced by members of the grass family, and include maize, barley, oats, wheat, millet, rye, rice and dari. Buckwheat, a starchy seed which, although not strictly a cereal, is usually associated with the cereals.

MAIZE. This cereal has been classified into about seven varieties but we need only concern ourselves at this stage with "dent" maize, known also as "Indian corn." This is a rich, golden brown or yellow, translucent seed; it is tooth shaped with a dent at the top, hence its name. An average seed measures $\frac{3}{8}$-inch in length and weighs about 45 to 49 lb. per cubic foot.

OATS. A spindle shaped, yellow seed, distinctly pointed at one end; an average seed measures about 7/16-inch in length and weighs about 30 lb. per cubic foot.

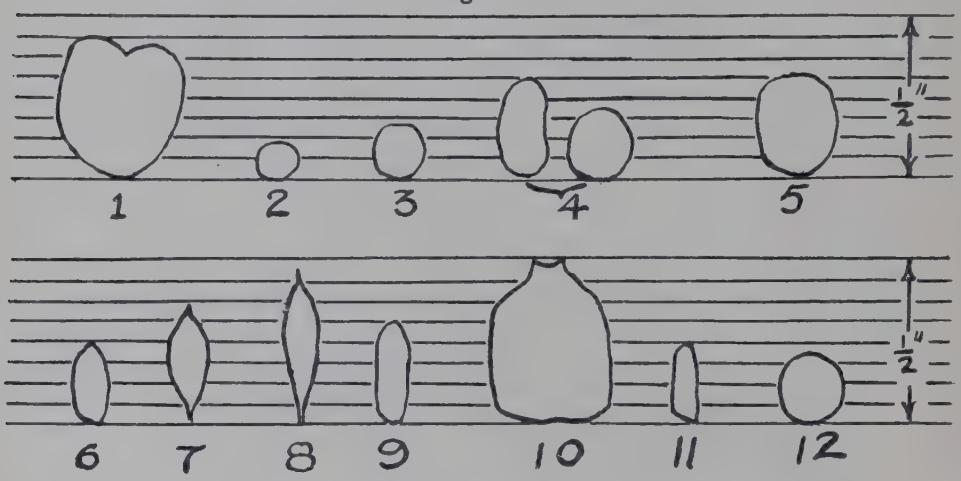
BARLEY. Stubby, spindle shaped, shorter and broader than oats and normally of a buff colour. Weighs about 36 to 39 lb. per cubic foot.

WHEAT. Yellow to red brown in colour. Blunt, spindle shaped to oval; not sharp pointed. A characteristic groove runs the whole length of one face. The apex is covered with a tuft of fine hair, apparent to careful scrutiny. The length is about $\frac{1}{4}$-inch and the weight 47 to 49 lb. per cubic foot.

RICE. The familiar white product of the grocer's shop is not nearly so important to feeding stuffs manufacturers as the bran and polish or polisher meal.

DIAGRAM SHOWING APPROXIMATE SIZE OF SEEDS

Fig. 50



1 GRAM 2 MILLET 3 LENTIL 4 SOYA BEAN 5 LOCUST BEAN
6 WHEAT 7 BARLEY 8 OATS 9 RYE 10 MAIZE 11 RICE
12 DARI

As harvested, rice consists of large, grey husks containing brown coated seeds. The husks are removed by threshing. When the brown skin is removed, a dull, yellow grain is revealed. This grain is polished with talc, the particles of grain removed constituting rice polisher meal. The brown skin or bran mixed with the polisher meal is known as Rangoon rice meal, the colour of which varies somewhat but an average sample is pale fawn or fawny grey, and weighs from 27 to 32 lb. per cubic foot.

MILLET. A round smooth coated seed about 2 mm. long. Yellow or light buff in colour, weighs 42 lb. per cubic foot.

DARI. Known also as kaffir corn. Hard shiny seed, nearly globular and about 4 mm. long; may be white or red in colour. Closely allied with milo maize and durrha. Weighs 51 lb. per cubic foot.

BUCKWHEAT. A sharp, three-angled fruit, 4 to 6 mm. long. Brown, or grey, or streaked brown grey in colour and weighs 40 lb. per cubic foot.

Cereal By-Products

From the cereals are manufactured several by-products which are of interest to the compound miller. Rice bran and meal have already been referred to; there remain, however, three important substances from the various industrial treatments of maize and these are as follows:

(1) HOMINY CHOP. A mixture of maize bran, germ, and some of the starchy parts of the kernel obtained during the manufacture of maize grits. The material weighs about 43 lb. per cubic foot.

(2) MAIZE GERM CAKE MEAL. The residue from the manufacture of maize germ oil, weighs 31 lb. per cubic foot.

(3) MAIZE GLUTEN FEED. The residue from the manufacture of starch and glucose (consisting of hard, rounded lumps) mixed with a proportion of maize bran. Weighs about 34 lb. per cubic foot.

(4) FLAKED MAIZE. Damp, gelantinized maize, heavily rolled and dried. Weight about 12 lb. per cubic foot.

Legumes

The next family of raw materials, the leguminous or pod-born seeds include two important members.

(1) SOYA BEAN, whose globular and bean shaped seeds of either yellow, buff, green, red, brown and black yield in the hands of the oil seed crusher the soya bean cake and extracted meal previously described.

(2) LOCUST BEAN. Long, stringy, rich brown pods containing up to a dozen very hard red-coated capsule shaped seeds. Locust beans have a distinctive sweet taste and a kibbled weight of 18 to 22 lb. per cubic foot. The ground meal weighs 45 lb. per cubic foot.

The remainder of the family is not so important and consists of

BEANS: Horse beans, broad beans, field beans, and haricot beans.

PEAS: Garden and field varieties. Weight about 49 lb. per cubic foot.

GRAM OR CHICK PEA: Greenish yellow to light brown seeds which are not quite so big as peas. Sometimes known as Indian pea.

LENTILS: Small, convex, lens-shaped seeds of red or yellow

to dark brown colour. The bran of lentils is obtained from the preparation of the seed for human consumption.

Miscellaneous

We now come to that long and variegated list of materials classed as by-products and miscellaneous. It is not intended that the following list should completely cover all the materials that might find their way into the compound mill, but it does enumerate some of the more common ones.

MALT CULMS. Also known as coombs, combs, sprouts and cummins. Light brown in colour and pleasant smell. A crisp product from the brewing process. May be adulterated with barley screenings. Weight about 15 lb. per cubic foot.

BREWERS' GRAINS. Like malt culms, a product of the processing of barley in the brewery. The residue from the mash bin after the extract has been run off. In the dried state, the grains are yellow, empty looking skins of a strawy nature weighing about 16 lb. per cubic foot.

DISTILLERS' GRAINS. The product of a similar process to brewers' grains, but may be the residue from a variety of materials such as maize, rye, rice and potatoes. Average weight is about 17 lb. per cubic foot.

SPENT YEAST OR DRIED YEAST. This is another by-product of the brewery. Flaky, cream to brown, with a bitter taste. Weighs 41 lb. per cubic foot.

BLOOD MEAL. Dried animal blood ground to meal and weighing 28 lb. per cubic foot.

COCOA MEAL. Cocoa bean shells ground into meal with an admixture of cocoa. Weighs about 37 lb. per cubic foot.

FISH MEAL. White fish meal is the residue from white non-oily fish; oily fish meal being inferior to the former.

MEAT MEAL. The ground waste products of the slaughter houses after degreasing. Weighs 39 lb. per cubic foot.

MEAT AND BONE MEAL. As meat meal, but with a larger percentage of bone. Weight, 43 lb. per cubic foot.

BONE MEAL. Ground, steamed bones after degreasing. Weighs [illegible] 51 lb. per cubic foot.

DRIED MILK. Familiar creamy, white powder made from the dehydration of cows' milk. Weighs about 25 lb. per cubic foot.

WHEY. Liquid [illegible] from the manufacture of cheese and dried into a creamy powder weighing 40 to 45 lb. per cubic foot.

DRIED GRASS MEAL. Green, cut grass in dry condition, and in appearance leaves nothing doubt of origin. Weighs about 33 lb. per cubic foot.

SUGAR BEET PULP. Residue from the extraction of sugar from beet. Has been described as having the appearance of light coloured tea leaves. Weighs 17 lb. per cubic foot.

MIDDLINGS OR THIRDS, POLLARDS, BRAN. By-products of

the flour milling process in order or coarseness, bran being the coarsest. Weights are 24 lb., 14½ lb., and 15 lb. per cubic foot respectively.

SALT. Either white or rock salt. Weight 56 lb. per cubic foot.

CHALK. Packed weight about 80 lb. per cubic foot.

TAPIOCA MEAL. Residue from the manufacture of starch from cavassa root.

MOLASSES. Brown viscous liquid left over from the evaporation of syrups in sugar manufacture. Weight 83 lb. per cubic foot.

COD LIVER OIL. Yellow oil with trace of fishy taste and smell. Source of vitamins supply.

MINERAL MIXTURE. One common mixture is a heavy, pink powder weighing 85-90 lb. per cubic foot.

SPICES. Certain materials known as spices are occasionally met with in the feeding stuffs industry and their use is a controversial subject. Some authorities maintain that good food does not need spices, whilst others claim medicinal properties for the spices. The merits of the spice as food does not concern us at the moment, but we should know those substances which are classified under the term spice.

The most common spices met with are fenugreek, aniseed and dillseed, and they may all be recognized readily by their distinctive, spicy smell. The spices are indigenous to south-east Europe and western Asia, but are also cultivated in the Mediterranean area, central Europe and India.

Impurities

IMPURITIES. This concludes the preliminary survey of the raw material characteristics, but mention ought to be made of the fact that many of the materials as received in the mill are likely to contain impurities of different kinds.

There may be present in a material :

(a) Other edible seeds or substances which need not be considered of any importance, unless the amount of the foreign seed or substance is great enough to constitute an adulteration of the raw materials.

(b) Poisonous or otherwise deleterious seeds or substances. For instance, charlock, corn cockle, castor seed, or darnel may be present and, at times, all these seeds have been held responsible for the illness or death of animals. Particular care is exercised to ensure that materials containing castor seed shall not be fed to animals. The most common occurrence of castor seed is in ground nuts and linseed.

(c) Sand and soil from the fields.

(d) Foreign articles like nails, coins, wood, stones and a long list of materials which are constantly being extracted by the millers' seed cleaning machinery.

CHAPTER III.

INTAKE OF MATERIALS

Having now briefly considered a representative selection of the raw materials which are to be manufactured into balanced feeding stuffs, the first job, obviously, is to get them to the mill; the second, to get them into the mill. The method of doing this will depend upon the nature and origin of the particular materials, the location of the mill, and the storage facilities at the mill.

If, however, all the more usual methods of intake are considered, it should then be possible to choose those which are most suited to particular materials and mills.

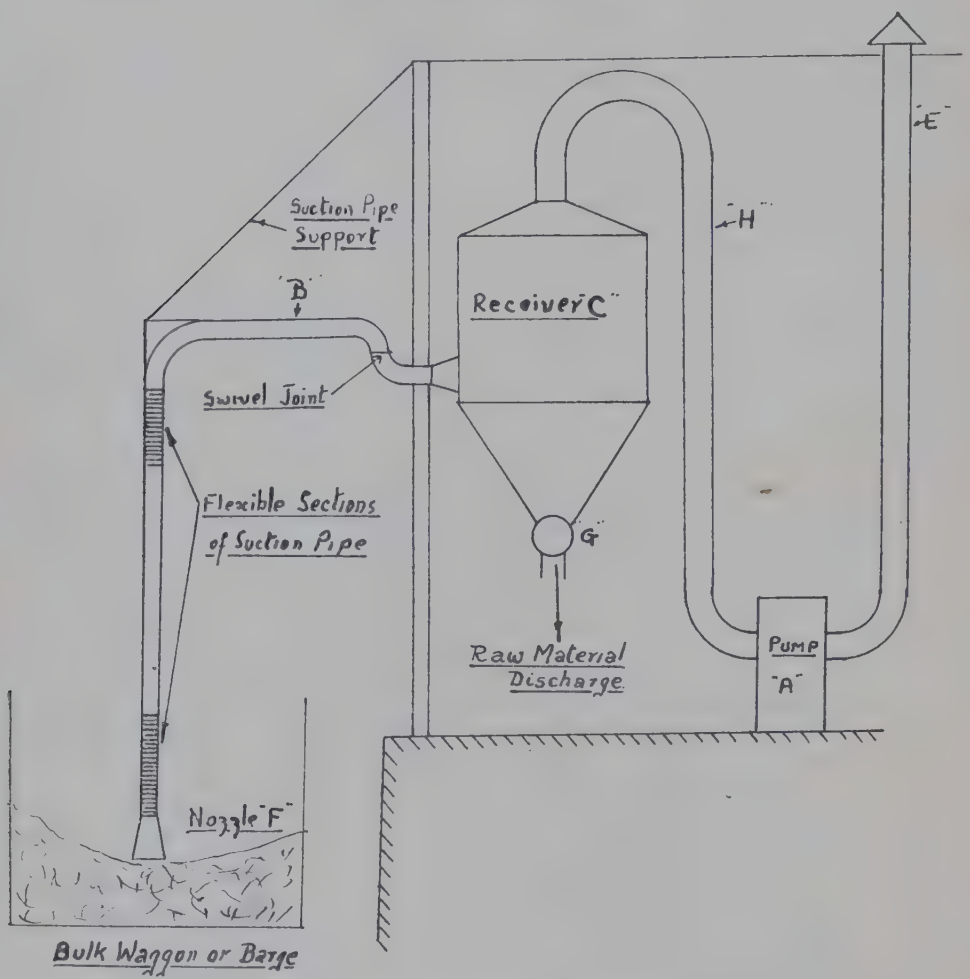


Fig. 51. Pneumatic Intake Installation

The materials may be delivered to the mill by road, rail or water traffic, and may be carried by all three services in bulk or in bagged form.

A large proportion of the raw material comes from overseas and is carried in ocean-going vessels which, upon reaching port,

usually transfer their cargoes to barges for transport to the quay stores. The store on the quayside may be part of the mill premises, or it may be managed by a storage company; on the other hand, it may simply be the sheds of a port authority. From this quayside store, whether it be a shed or a silo, the material is removed by motor vehicle, railway waggon, or barge, to the millers' warehouses. The mill which is situated upon, or adjacent to, a navigable waterway is almost certain to be served by all three forms of transport mentioned, and is therefore likely to have installed all the following types of intake plant:

FOR BULK MATERIAL

Pneumatic elevators.
Bucket elevators.

FOR MATERIAL IN BAGS

Rope or friction hoist.
Bag elevators.
Inclined conveyors.

(N.B.—Bags containing material may be cut open at the mill and the contents tipped into a hopper feeding a bulk intake unit).

CAKES IN SLAB FORM

Inclined conveyors.
Slings attached to the rope of a friction hoist.

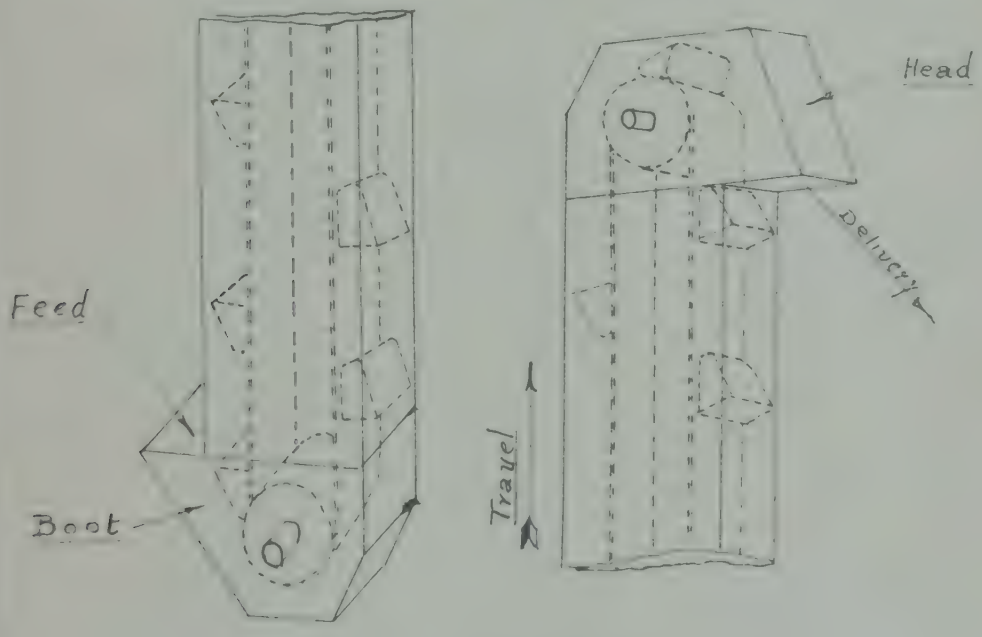


Fig. 52. Bucket Elevator

Pneumatic Elevator

A pneumatic elevator is a handling device using air as the carrying medium, and consists of a machine for moving large volumes of air, a means of connecting the moving air with the raw material and the storage point, and a device for separating the material from the air at the delivery end.

A common type of plant used to meet this specification consists of a reciprocating pump for moving the air, a long steel pipe along which the air carries the material, and a separating chamber wherein the materials are removed from the air stream. There are, of course, many refinements and additions to these three basic items found in practice, two of which, an air filter and a discharge lock, may be considered primary necessities.

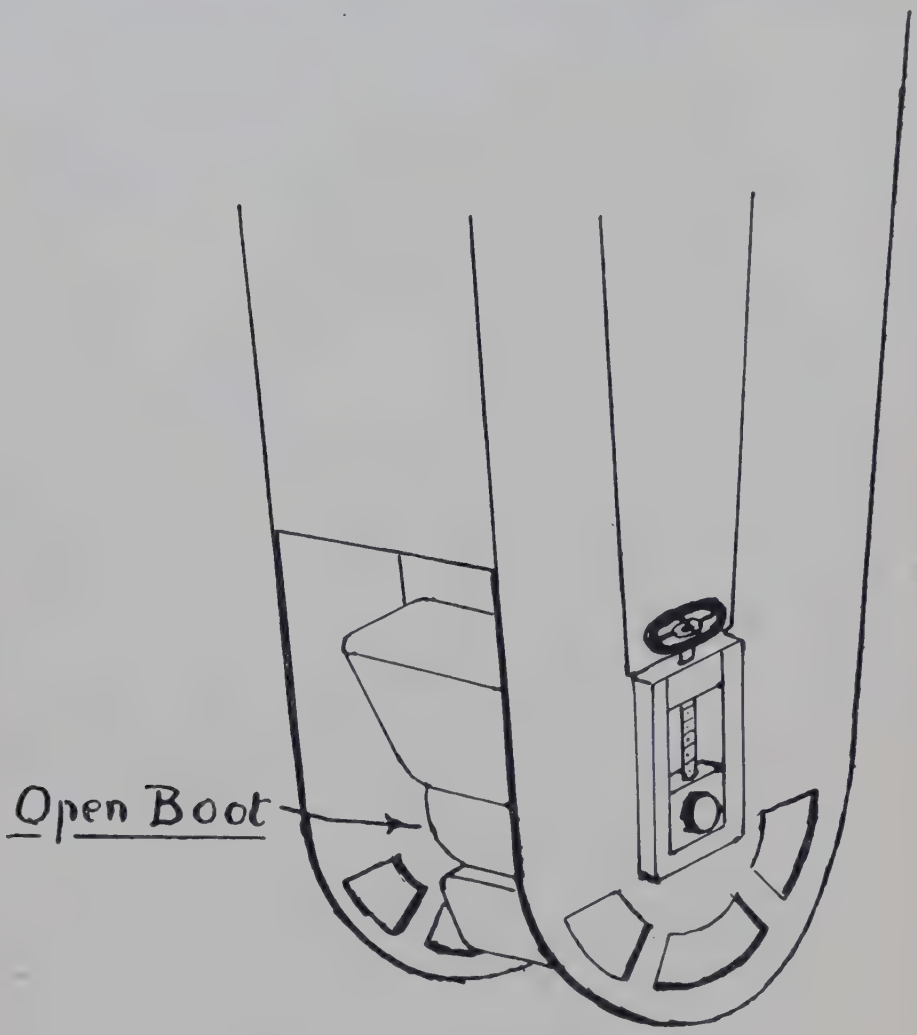


Fig. 53. Barge Elevator Boot.

The diagram of the pneumatic intake installation illustrates the relationship between the parts named and should give a general idea of the working principle (Fig. 51).

The pump A sucks air along the pipe B, through the separator C and discharges through the exhaust E. When the nozzle F at the end of pipe E is fed into the raw material, the air entering the nozzle carries with it a stream of raw material until the air and the material is separated at C. The raw material is discharged through the airk G, and the air travels on to the pump through pipe H.

Bucket Elevator

A bucket elevator is a handling device using specially shaped buckets fastened to an endless band as the carrying medium. A common type of elevator has a cotton canvas, or balatta belt passing round two pulleys mounted one above the other, the distance between the pulleys being determined by the height to which the elevated material has to be raised. Fastened to the

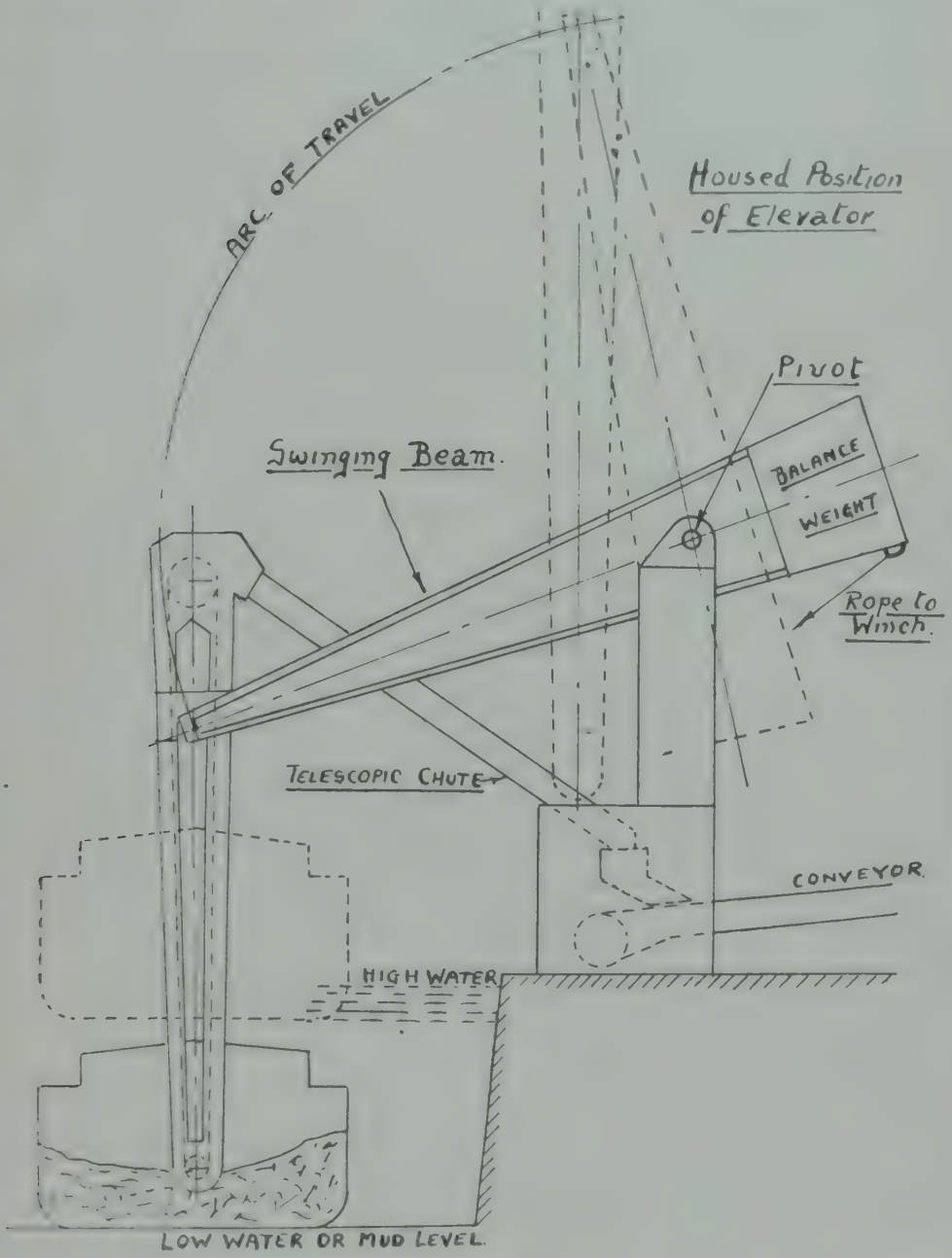


Fig. 54. Barge Elevator

belt at regular intervals are the buckets whose shape varies with the nature of the materials to be handled. The pulleys, with the belts and the buckets, are contained in a casing which forms a complete closure except for an aperture at the bottom of the elevator to receive the material to be elevated, and another aper-

ture at the top through which the elevated material is discharged.

The top and bottom of the elevator are usually referred to as the head and boot respectively.

The belt carrying the buckets is driven by the head pulley, whose shaft is connected outside the elevator to some source of power, commonly an electric motor.

Fig. 52 illustrates the main lines of a typical bucket elevator.

For intake purposes, an elevator of the type shown will be fed from a hopper located conveniently to the transport vehicle.

For the discharge of bulk materials from barges, however, the boot of the elevator is modified by the removal of a length of the distance plate. (See Fig. 53). This allows the elevator to sink into the material it is handling and so to feed itself. An elevator of this type, known as a barge, or ship elevator, is carried on a pivoted beam, which allows it to be lowered into a barge or raised out of the way when not in use. (See Fig. 54).

Friction Hoist

This is a very widely used machine for the elevating of bagged materials and, in fact, it may be adapted for handling materials in many different kinds of packages.

The hoist consists of a winch, usually housed in the top storey of the building. Attached to the barrel of the winch is a rope, or chain, to which the bags to be lifted are fastened. Control of the lifting rope is obtained by bringing a friction wheel attached to the barrel shaft into and out of contact with a constantly rotating friction pulley on the driving shaft. As soon as the barrel shaft is taken out of contact with the driving shaft, it begins to run backward under the weight of the lifting rope and any load that may be attached to it. To hold the load, the

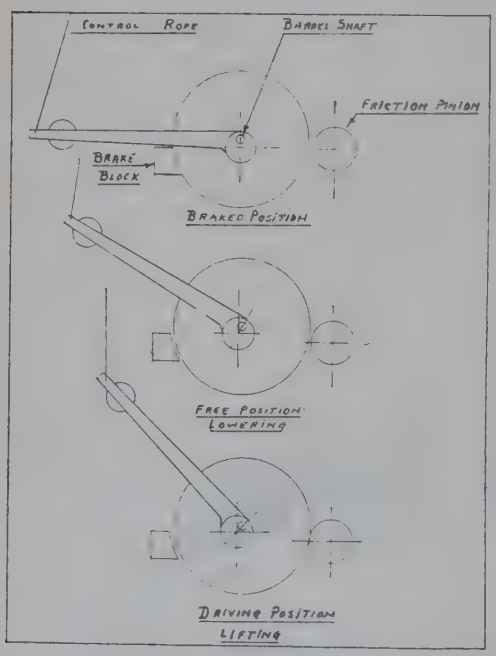


Fig. 55. Friction Hoist.

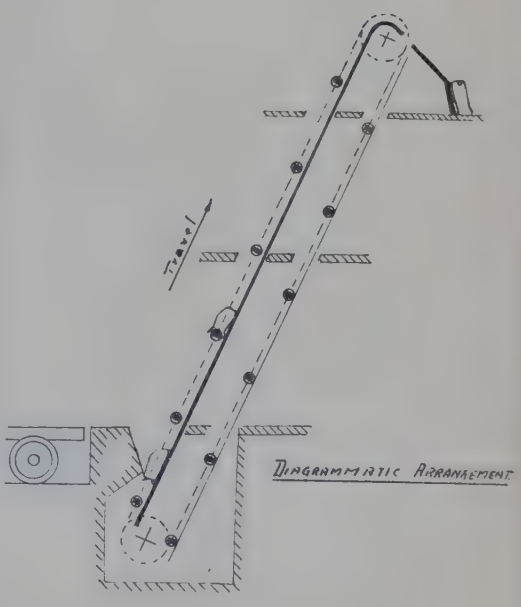


Fig. 56. Inclined Sack Elevator.

barrel shaft friction wheel is moved into contact with a fixed brake block (Fig. 55).

By the movement of the barrel shaft, therefore, the load may be lifted, held stationary or lowered. The movement of the barrel shaft is obtained by either mounting one end of the shaft in an eccentrically housed bearing, or by running the barrel on a non-rotating spindle, both ends of which are eccentrically housed. The movement of the control rope is imparted to the eccentric through a loaded lever, which automatically moves the barrel shaft into the braked position if the control rope is released.

The sacks of material to be lifted are usually gripped in a running noose formed in the end of the lifting rope, but when the hoist is used for handling cake in slab form, a sling, usually of cotton canvas, is attached to the end of the lifting rope.

Some few materials, such as dried milk powder, are delivered to the mill in barrels, and here again, the friction hoist demonstrates its versatility by handling the barrels, usually in a chain sling attached to the lifting rope.

Sack Elevators

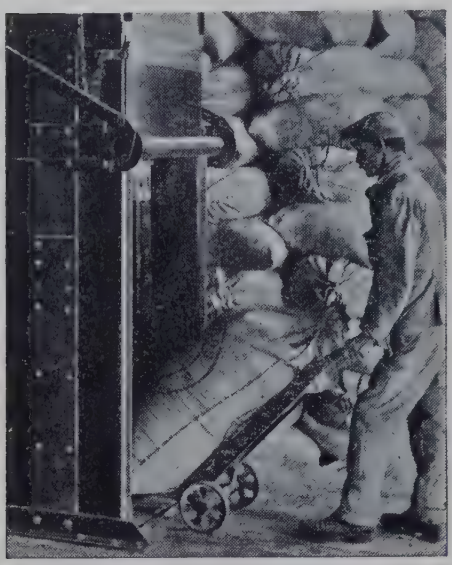
These may be vertical or inclined, fixed or portable, and in each of these categories a variety of designs persist. A common type of inclined elevator is shown in Fig. 56. The elevator consists of a sharply inclined ramp up which bags are slid by carrier bars; these are fastened at either end to endless chains which pass over suitable sprockets mounted on shafts at the top and bottom of the elevator. The position of the shaft carrying the sprockets at the bottom of the elevator can be adjusted to keep the chains at a suitable working tension.

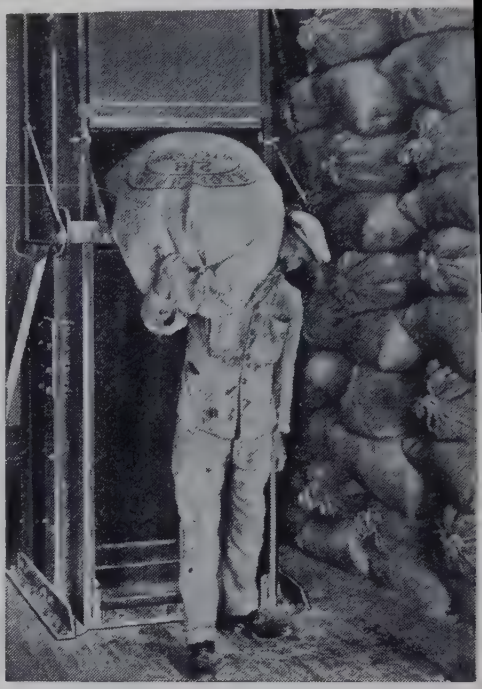
The elevator is driven by connecting the top sprocket shaft to a source of power, commonly an electric motor driving through suitable reduction gearing. The bags are fed on to the elevator down a feed chute, and are mostly delivered at the top of the machine by being discharged at the point where the bars commence their journey down the return side of the elevator.

Portable sack elevators are of the inclined elevator design, but the elevator, complete with its drive, is mounted on a wheeled chassis and taken to the place where it is needed either under its own power or by being towed.

The vertical sack elevator is a similar machine to the inclined elevator, in that the bags are carried, or pushed, by bars attached to endless belts or chains, but the plane of movement is now vertical and in the accompanying illustrations, the whole of the path of the bag is enclosed in a steel casing. The steel casing is made with openings at various floor levels, and the opening of any door brings into the path of the bag a throw off plate which tips the bags off the elevator through the door opening (Fig. 57).

A feature of the elevator illustrated, is that the delivery of the bags is made on the same side of the elevator as that on which they are fed.





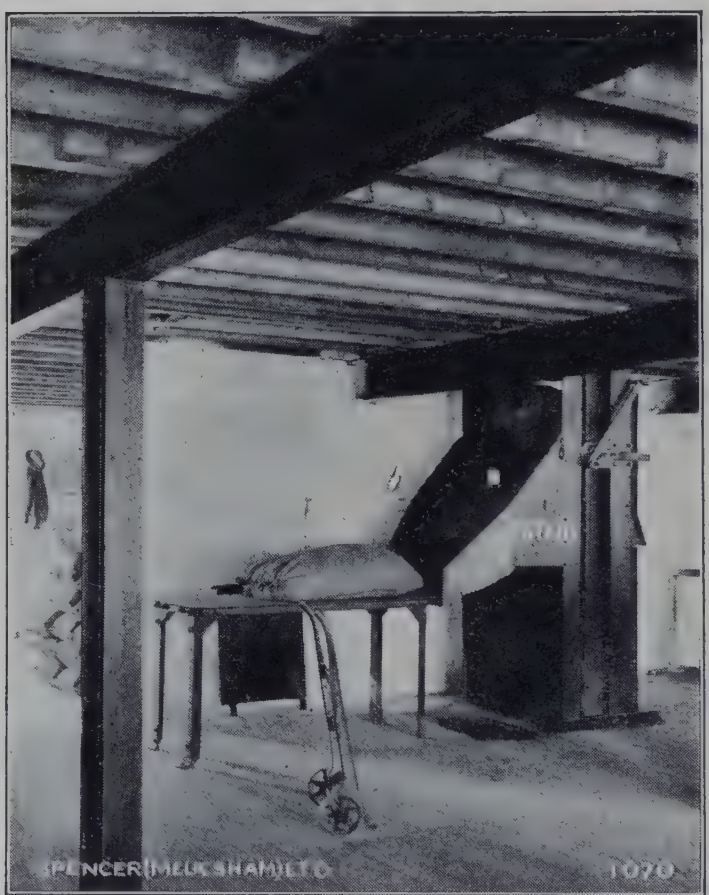


Fig. 57. Vertical Sack Elevator showing loading; intermediate discharge and head discharge

Another type of sack elevator, known as a swinging tray elevator, discharges the bags upon the opposite side to which they are fed.

In this elevator, the bags are carried on combe pattern trays which are free to swing between the chains by which they are carried. This feature allows the bags to be carried over the headshaft without spilling and at the discharge points, the bags are lifted from the trays by a combe-shaped take-off plate whose teeth coincide with the spaces between the teeth of the elevator trays.

Inclined Conveyor

This is a special case of an inclined elevator in which the slope of the elevator is small, and the design follows more closely the design of conveyors. Inclined conveyors never push the bags, but carry them on an endless band, or upon one of the wide variety of slats used for this purpose. In the machine using slats, the latter are fastened at each end to endless chains which are tensioned and driven in a manner similar to that mentioned for the inclined sack elevator. All elevators having slats, or bars, as the carrying members, usually have runners fitted to the chains at intervals or on the ends of each bar. The runners travel on guides up each side of the conveyor.

It may be noted that portable elevators are used chiefly for the stacking of raw materials and manufactured products, and will be discussed under that heading. The exception to this is the ship elevator mounted on a wheeled chassis running on rails, but here the travel is limited to that necessary for the elevator to serve vessels lying along the length of the quay, and in some cases, to the length of the barge only.

Molasses Intake

No mention has yet been made of the method of receiving bulk molasses. This important commodity usually arrives at the mill in tank waggons by rail or, more commonly, by road. The tank mounted on the waggon may be heat insulated, and the molasses contained in it may be under pressure.

The pressure tank is used where there is not a good natural fall into the receiving tank in the mill, and, of course, it reduces the time needed to empty the waggon. With a normal gravity discharge from the waggon, the molasses may run in a short, open trough into the store tanks. With pressure discharge, a flexible hose will lead the molasses into the tanks. The work of handling molasses is considerably eased when the molasses is kept warm and heat insulation of tanks is an asset.

CHAPTER IV.

FEEDING OF INTAKE ELEVATORS

All the intake elevators mentioned need to be fed with the materials they are to handle, and although it may seem un-

necessary to state this obvious fact, the ease with which it can be fed is an important characteristic of intake elevators.

With pneumatic elevators, it is simply a case of applying the suction nozzle to wherever the material may lie. A ship elevator of the bucket type, too, will discharge a considerable bulk of the material by sinking into the pile, but it will be noted that when the barge is becoming empty, the remainder of the material will be out of reach of the elevator boot and will need to be shovelled to it.

Bucket elevators receiving from rail or road bulk waggon are usually served by a receiving hopper, from which the material

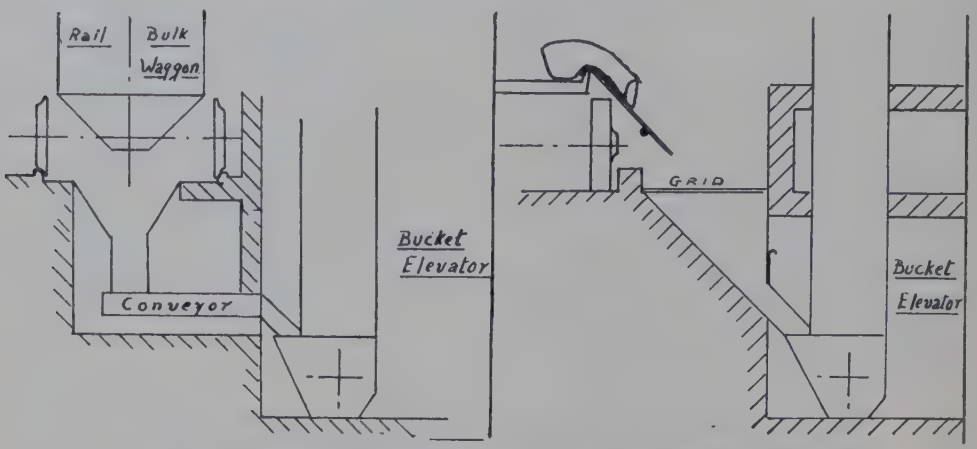


Fig. 58. Bucket Elevators receiving from Rail and Road

gravitates into the elevator, but in some cases a feed conveyor is necessary to take the material to the elevator boot. Receiving hoppers are fitted with a grid which helps to hold back large pieces of foreign matter which may be in the load. Typical arrangements are shown in Fig. 58.

Usually, inclined sack elevators can be fed direct from the waggon, but vertical sack elevators are sometimes located in such a position that the bags have to be trucked or otherwise conveyed to them.

The feeding of a sack elevator not fitted with an automatic feeding device requires the attendant to exercise care to avoid tipping a bag across a carrier bar instead of above it. Bags badly loaded may jam in the casing, causing considerable damage, and may easily result in a broken chain.

The lifting rope of a friction hoist must, of course, be situated immediately above the waggon from which it is being fed. Where the roadway is outside the building line the lifting rope is led outside the building by passing over an idler pulley erected in a structure known as a cathead. A cathead consists of two beams projecting out of the building, and spaced to allow the cathead pulley to run freely upon the spindle erected between them. Between the cathead pulley and the winch the beams may be splayed to allow the lifting rope to traverse the length of the winch barrel.

CHAPTER V.

PRELIMINARY CLEANING AND STORAGE

Having got the raw materials as far as the delivery point of the intake elevator or conveyor, we are now faced with the problem of holding them in store until they are required for the manufacturing process, and in certain seasons, the storage time may extend over a period of many weeks.

The nature of some materials demands that they be used as soon as possible, whilst other materials will store without harm for quite a long time.

The storage of raw materials in the feeding stuffs industry is complicated by :

(*a*) The wide range of different materials which have to be kept separate.

(*b*) The variation in physical and chemical characteristics, such as size, shape, oil and moisture content.

(*c*) The variation in the size of the parcels of the different materials.

This complication has tended to retard the adoption of large scale bulk storage, and explains why the costlier bag storage still finds so many adherents. The situation is much easier for the provender miller, whose materials consist largely of cereal grains.

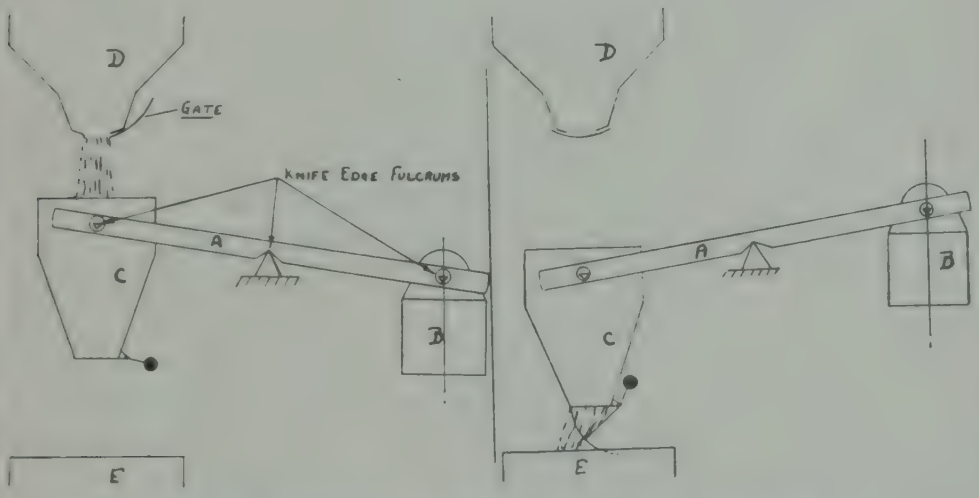


Fig. 59. Automatic Weigher Filling and Emptying

All materials received into the mill should be weighed before storing, although this is not universally done. With the purchasing of materials imported from abroad, weighing at the mill may be considered unnecessary, as master porter's weights have usually to be accepted for contract of sale purposes. In spite of this, however, the weighing of material coming into the mill affords information necessary to the proper assessment of mill performance, as well as a check on purchases.

Bulk Materials

Bulk materials delivered by road may be weighed in the road vehicle on a public or private weighbridge, but a more convenient method is to pass the material through an automatic weighing machine.

Automatic weighing machines vary considerably in design, but the majority are based upon the principle of the simple beam balance, with refinements to secure continuity of operation with speed and accuracy of weighing.

The principle of operation is illustrated by Fig. 59, in which a beam (A), having a weight box (B) at one end, a weigh pan (C) at the other, is balanced on a knife-edge fulcrum. The bottom plate of the weigh pan (C) is constructed in the form of a door, or gate, through which the weighed material can be discharged. The weight box (B) is loaded to the desired weight, and the material to be weighed is fed into the weigh pan from a hopper (D) which is designed to hold at least one weighment of material.

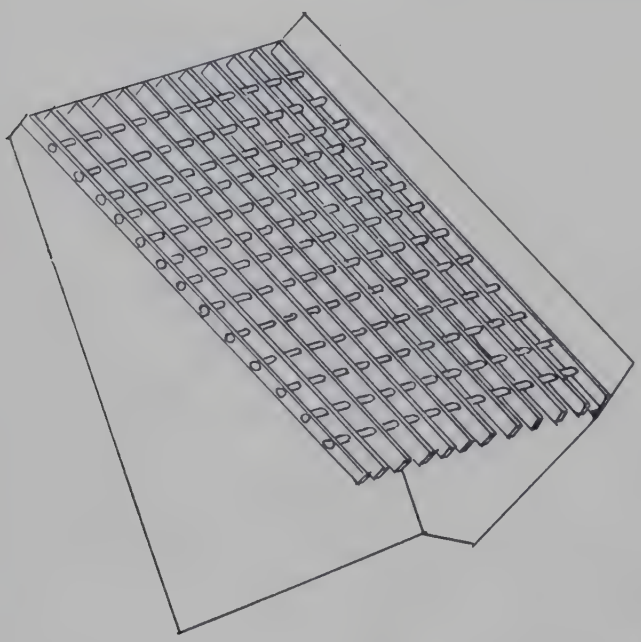


Fig. 60. Intake Screen
Front and nearside plate removed to show grid

The flow of material into the weigh pan is controlled by an automatically operated gate which forms part of the hopper (D). As the weigh pan fills with grain and begins to sink, the movement of the beam firstly operates the gate closing mechanism of the hopper (D) and cuts off the feed to the weigh pan, and, secondly, opens the weigh pan discharge gate, allowing the weighed material to flow into the hopper (E) below. The weigh pan is then returned to its original position by the action of the weights at the other end of the beam, which action automatically closes the weigh pan gate and opens the feed gate of hopper (D).

No actual weighing machine mechanism is quite as simple as is suggested by the foregoing illustration. One necessary refinement is the arrangement for thinning out the feed near the end of the filling part of the cycle in order to reduce the effect of the grain's momentum. One such device closes the main gate (D) before the full weight is on the scale, and dribble

feeds the last few pounds through the opening of a much smaller gate.

Another method adopted is nearly to close the feed gate before the full weight of grain is passed through, and let the last few pounds flow through the reduced gate opening.

It will be noticed from the diagram, that after the feed gate is closed, some seed will be in the course of falling into the pan in excess of the amount which has operated the gate closing mechanism and this must be allowed for.

A simple device which compensates for this " gate-crashing " handful of material, consists of a lever hinged at the fulcrum of the beam, and carrying an adjustable weight. The position of the weight is set in the following manner : The release gate of the weigh pan is locked shut ; the pan is then filled by the machine in the normal way until the feed gate is closed, when it may be found that the weighment is too heavy. This is counteracted by swinging the hinged lever over to the weight box side of the beam and altering the position of the adjustable weight until the beam balances.

The weigh pan gates are then opened and the hinged lever, with its weight, is swung over to the weigh pan side of the beam to act with the material which is being weighed, thus reducing the quantity needed to tip the scale, by the amount by which the previous weighment was too heavy.

A further refinement is an interlocking device which prevents both the feed hopper gate and the weigh pan discharge gate being open at the same time. Each weighment of material is of a predetermined weight, and each tip of the scale is recorded on an automatic counter.

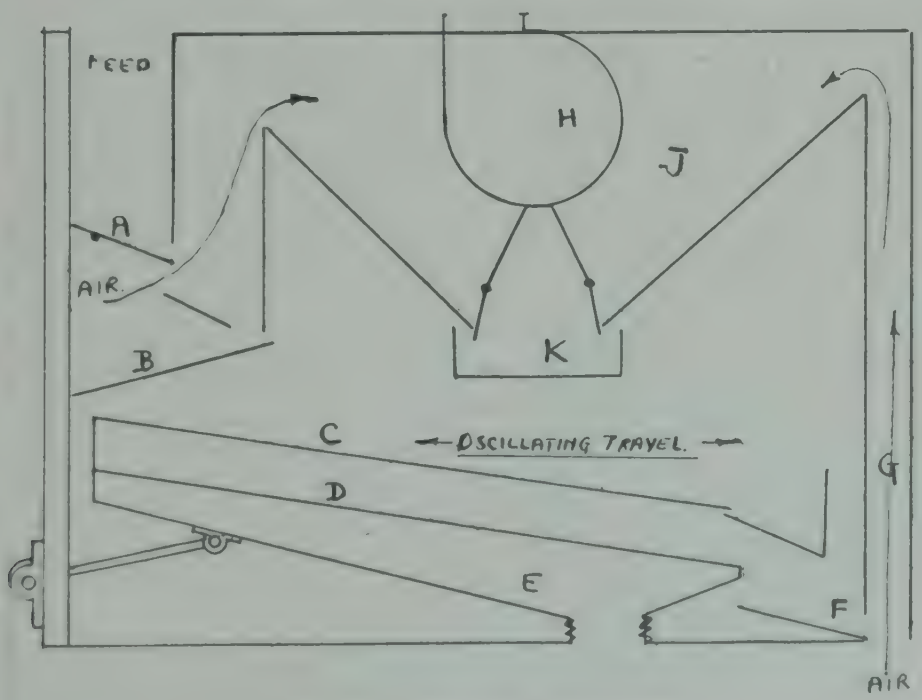


Fig. 61. Receiving Separator

Preliminary Cleaning

Bulk materials, as well as being weighed, are usually subjected to a preliminary cleaning process before being fed into the storage bins. This cleaning may be confined simply to passing the material through a coarse, fixed screen of the type shown in Fig. 60, which holds back sticks, string, large stones, tramp iron, etc., or as is more particularly applicable to provender mills the material may be treated by the action of machines such as the receiving separator, the reel, the scalperator and the rubble separator.

The Receiving Separator is shown in Fig. 61. The grain enters through balanced feed gates (A), and passes through a preliminary screen (B) which removes string, sticks, etc. The material now passes through screen (C) whose perforations are small enough to hold up material which, although able to pass through screen (A) are larger than the particles of grain from which they are separated. The third screen (D) will not allow the grain to pass through it but its perforations are sufficiently large to allow sand, soil, etc., to be discharged into the

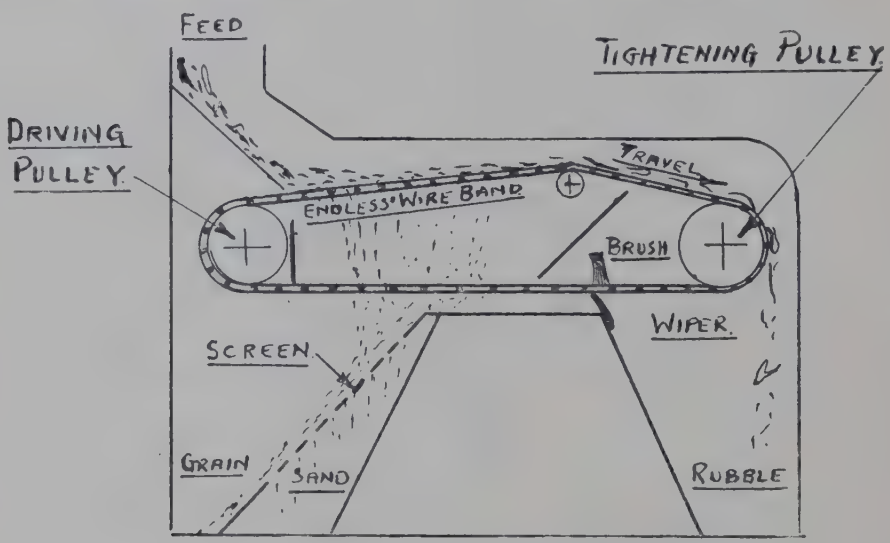


Fig. 62. "Apex" Rubble Separator

chamber (E). The cleaned grain is discharged through the gate (F) where it is subjected to aspiration by air flowing up the duct (G) under the action of the fan (H).

In the chamber (J), the air flow velocity is reduced by expansion and the supported dust drops to the discharge outlet (K). A primary aspiration is given at the feed point (A) and the aspirating air, after passing through the pan, is re-circulated to the points (A) and (F).

The cradle carrying the screens (B), (C) and (D) is given a reciprocating motion to convey the material through the machine and help the screening process.

The "Apex" Rubble Separator is shown in Fig. 62, and the method of operation should be clear from the diagram.

The coarse endless mesh band through which the grain passes, holds back the larger impurities, and discharges them into the rubble chamber on its way round the tightening end pulley. The grain which has passed through the band is projected down the sand screen where the sand and soil are separated from the grain.

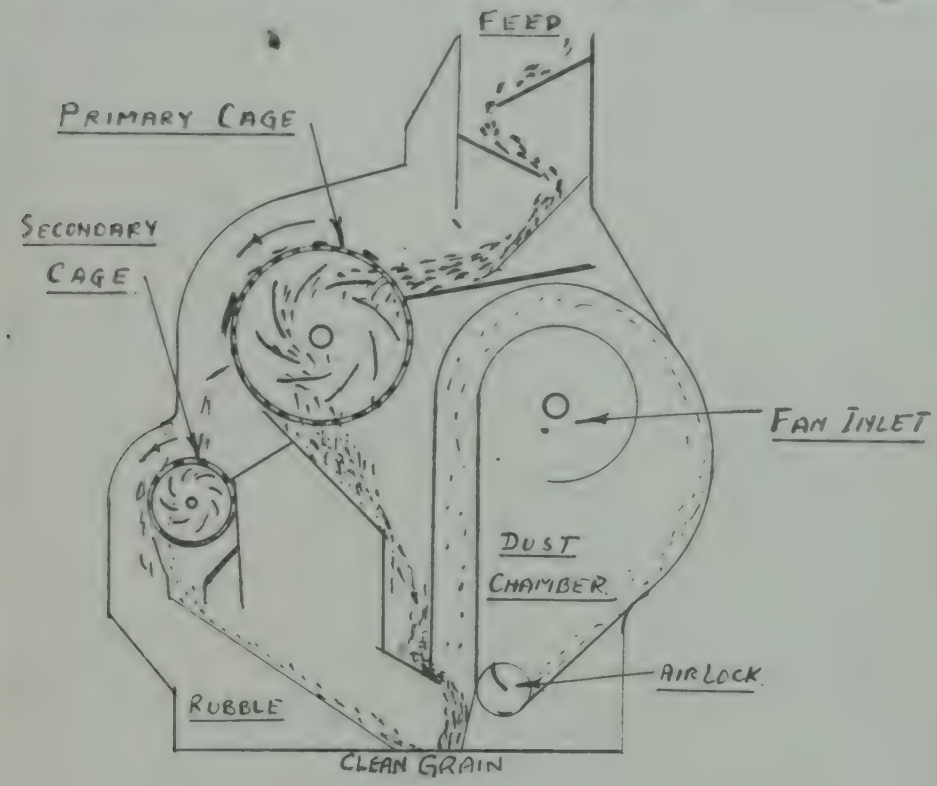


Fig. 63. Scalperator

The Scalperator is a machine in which use is made of a revolving wire cage containing spiral vanes. The material to be cleaned is fed evenly over the length of the cage. The good grain and smaller impurities pass through the mesh, the rubble being tailed over by the rotation of the basket. A secondary cage is interposed into the flow of rejected rubble to salve any good seed that may have travelled over the primary cage on pieces of paper, etc. The cleaned grain, before being discharged from the machine, is subjected to a current of air, which effectively removes entrained dust, Fig. 63.

The Reel is a large diameter cylinder, usually of perforated sheet metal, but may be made of heavy wire mesh. For grain, the cylinder is perforated with two different sizes of holes, each size of hole occupying a separate section of the cylinder's length. The cylindrical screen is mounted on a shaft whose axis is inclined to the horizontal. The shaft is driven at a speed of about 25 r.p.m., and the material to be cleaned is fed in at the high end.

The first section of the cylinder contains the smaller perforations through which sand and soil are removed. The second section contains perforations through which the grain passes.

leaving behind the sticks, straw, stones, etc., which are tailed over the lower end of the cylinder.

MAGNETIC SEPARATORS.—It is convenient at this point to refer to the removal of the magnetically sensitive impurities iron and steel, by the action of magnetic separators. The proper place to remove such tramp iron small enough to escape the preliminary cleaning screens, is undoubtedly in the process flows rather than in the intake flow, but many intake plants include magnetic separating devices which are additional to the magnets incorporated in the process flows.

Magnetic separators fall into two broad divisions :

(1) Self cleaning.

(2) Non-self cleaning.

The self cleaning class may be further divided into those separators which continuously discharge the separated tramp iron, and those which discharge the tramp iron in batches.

Continuous discharge, self cleaning separators :

(a) Magnetic pulley.

(b) Magnetic drum.

(c) Magnetic overslung conveyor.

MAGNETIC PULLEY.—Usually occurs as the discharge end pulley of a short belt conveyor in which the band is thin, cotton canvas, but may be found in a similar position in a normal belt conveyor. One type of pulley has its face built up of magnetic

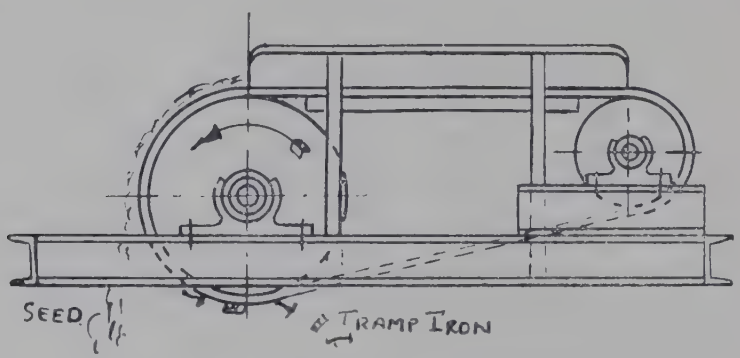


Fig. 64. Magnetic Pulley Separator

bars separated by narrow non-magnetic strips; another type presents a plain magnetic face. The belt carrying the material to be cleaned passes round the magnetic pulley which is driven in the normal manner. The tramp iron does not leave the belt at the same time as the grain or meal, but is held by the magnetism of the pulley until the belt, leaving the pulley face, pulls the iron free to discharge it. (Fig. 64).

OVERSLUNG CONVEYOR.—This separator is used to remove particles of iron and steel from material being carried on a band conveyor. A magnet, mounted clear of the materials being conveyed, has its magnetic field extending over one or both edges

of the conveyor band (Fig. 65). A belt mounted on suitably located pulleys travels between the magnet and the material to be cleaned in a direction at right angles to the main conveyor. Separated iron is held on to the cross belt by the magnet above until the iron is conveyed out of the magnetic field, by which time, it is also clear of the main conveyor band.

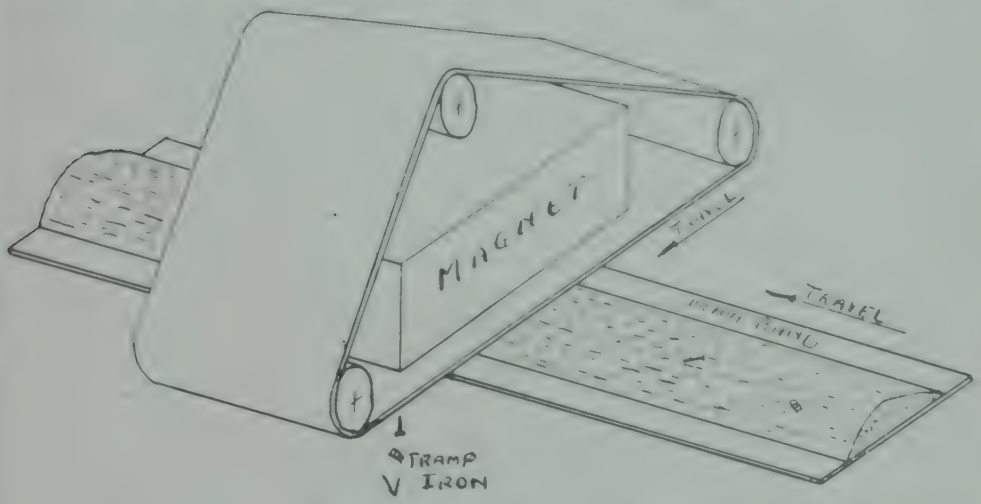


Fig. 65. Overslung Conveyor

MAGNETIC DRUM.—The magnetic drum differs from the magnetic pulley in that the magnets in the drum are stationary, and their magnetic attraction is limited to just less than half the circumference of the drum. The drum, which is made of some non-magnetic material, usually brass, revolves upon the stationary shaft which carries the magnets. The material to be cleaned is fed on to the drum as shown in Fig. 66. The separated tramp iron is held until the revolving drum carries it out of the influence of the magnet, when it is dropped into a box. The stationary magnet assembly can be moved through a small arc to suit particular working conditions.

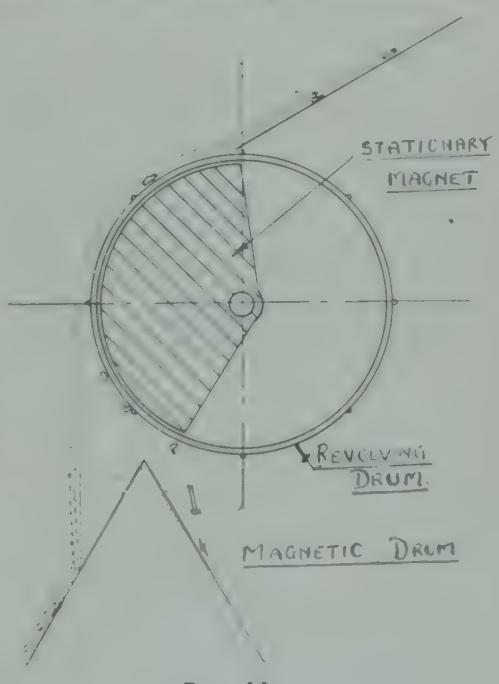


Fig. 66

SELF CLEANING BATCH DISCHARGE SEPARATOR.—The sole representative of this class is the magnetic chute, whose magnetism can be turned on or off at will. As the name suggests, this separator takes the form of a short chute, under whose

bottom plate is mounted a number of magnets. Material flowing down the chute passes through the magnetic field, and iron and steel articles are held by the chute. The bottom plate of the chute is commonly stepped, with a recess under each step. The recesses are usually located at points of maximum magnetic attraction, and material attracted into them is thus drawn out of the stream of material passing down the chute (Fig. 67).

Immediately following the magnetic section, a short length of the chute bottom plate is pivoted and so arranged that it swings open when the magnetic field is switched off (Fig. 68). As soon as the material held on the chute is released from the pull of the magnets, it falls down the chute and out of the opening made in the chute by the operation of the pivoted flap. This device also diverts any material which may flow down the chute whilst the magnets are not working.

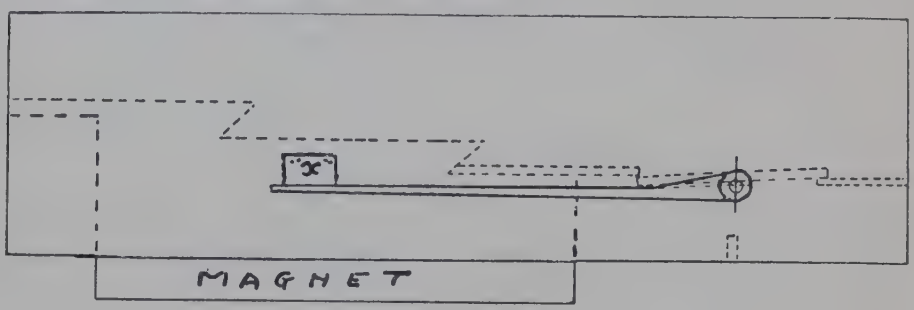


Fig. 67

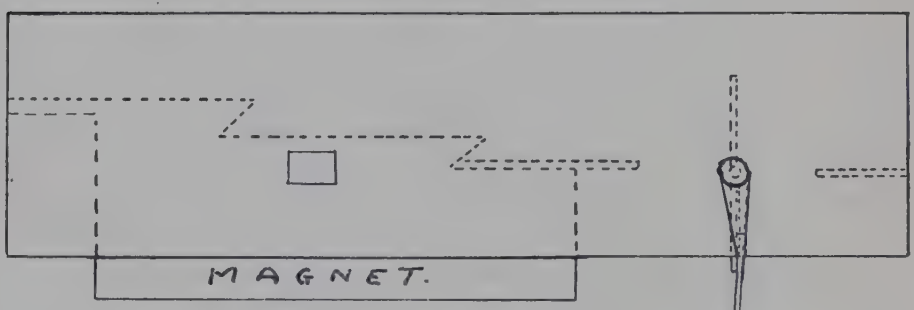


Fig. 68

Magnetic Chute showing Pivoted Plate Closed and Open

All the separators mentioned may be fitted with either "permanent" or electro magnets. The permanent magnets have the advantage of being completely self-contained, and are very efficient for shallow depths of flow, say, up to 1 inch thick. The self cleaning permanent magnet chute is fitted with a flux control device which allows the magnetic force to be short circuited before passing through the bottom plate of the chute.

For greater depths than one inch, electrically excited magnets should be used. With good electro magnets, quite deep flows of material can be cleaned, but in all cases the depths should be kept as small as possible.

Electro magnets are subject to the maintenance of the electric supply, and provision must be made against the failure of this supply either by alarm signals or flow stopping devices. For example, the failure of the electric current feeding an electro magnetic chute operates the pivoted flap previously referred to, by removing the magnetism from the block "x" which holds the flap in the closed position.

The non-self cleaning class of separator is represented almost exclusively by the permanent magnet chute without flux control. Here, the separated iron and steel has to be removed from the magnet by hand picking.

Storage

The bulk materials, having now been subjected to weighing and preliminary cleaning, are ready to be put into store. The storage of bulk materials quite obviously involves the use of bins. It has been pointed out that many complications arise in the storing of compound ingredients in deep bins. These complications will be considered fully at a later stage, and for the present, it will be assumed that it has been decided to use bin storage.

The bins may be deep or shallow, and the warehouse containing the bins is known as a silo, although the name silo is frequently used when referring to one deep bin. There is no sharp dividing line between deep and shallow bins, but generally, a bin over about forty feet deep is classed as a deep bin or silo. The bins may be constructed of brick, timber, steel or reinforced concrete. Brick construction is heavy, and the foundations may impose a limit to the height of building. Brick bins usually have steel hopper bottoms.

Timber is light compared with brick. It is, or was, cheap, and a suitable method of construction eliminates the need for corner columns. It is not a good conductor of heat, but the inside surface may facilitate the arching of "difficult" materials.

Steel was originally very economical in space by virtue of the thin walls, but because of its high heat transferring properties, present day construction calls for an air gap of up to six inches between bin and bin. Without controlled ventilation sweating is likely to occur on the cold plates. Low friction between steel and the stored material helps to prevent arching. The gas-tight form of construction makes possible the use of carbon dioxide in the control of heating.

Reinforced concrete is comparatively light, strong, convenient to erect, and affords a very good alternative to the other

constructional materials. Its rough surface is a disadvantage which can be lessened by proper treatment during casting, although for many compound materials, steel hopper bottoms are necessary.

Plan shapes of bins may vary from square and octagonal to round. For shallow bins, steel is perhaps the most common constructional material and, in the main, proves very suitable.

A constant check must be kept on the temperature of material in deep bins, and this is made possible by the fitting in the bins of heat sensitive devices, such as electrical resistance wire. The well known variation with temperature of the electrical resistance of wire is used as a basis of temperature reading, and deep bins will have a number of special fittings carrying resistance wire whose resistance variation is recorded on the temperature scale of a meter located outside the bin.

In the event of heating, facilities should be available for turning over the material involved. Turning over means drawing the material out of a bin and returning it to that bin, or another bin, through a conveying system. The aeration the material receives during conveying being usually sufficient to arrest the heating up process.

Various other devices are associated with bin storage, one being a grain distributor which minimizes the separation which occurs between particles of grain of different weights. Heavy grains have a tendency to accumulate in the centre of a bin, and to be discharged first. The distributor feeds the heavy grains to the sides of the bin which ensures a more even sample when drawing off from the bottom of the bin. Another device is a bin discharger which is essential to the drawing off of many materials which display a reluctance to leave the bin. A further item of auxiliary equipment is a bin hoist, by which the inside of the bin may be traversed for inspection and repair work.

Conveyors for Bulk Material

In the handling of bulk materials a variety of designs of conveying machines are used, the most common being :

(1) Belt or band conveyors.
(2) Screw or worm conveyors.
(3) Scraper conveyors.
(4) Drag link conveyors.
(5) Gravity bucket conveyors.

The type of conveyor used will depend upon the conditions obtaining in particular circumstances. Most of the deciding factors can be expressed in practical terms, but it is true that personal preferences and prejudices will often play a large part in the choice of equipment.

1. Belt conveyors consist of a belt, or band, usually of woven cotton or balata, running over two pulleys, located at the

extreme ends of the conveying distance. The pulley at the end of the conveyor, where the material is fed on to the band, is referred to as the tightening end pulley, for it is this pulley whose position is usually adjusted to maintain the conveyor belt at a suitable working tension. It should be noted, however, that belt tension may be adjusted in a variety of ways, some of which operate automatically. The belt, which may be run flat, or troughed, is supported over its length by idler rollers mounted on the conveyor chassis.

A common method of driving the belt is to connect the delivery end pulley shaft to some source of power, although there are variants of this. The material is fed on to the band via a feed shoe, which feeds the material as near in line with the direction of travel as possible. The conveyed material is discharged from the belt by a travelling throw-off or tripper. Where intermediate discharge is not required, the material is simply conveyed over the terminal pulley into a chute or bin.

2. Screw or worm conveyors make use of a spiral blade wound round a tube, or bar shaft, the whole being mounted in a "U" shaped trough.

Design of blade varies, and for certain jobs, separate blade sections, known as paddle blades, are used. The material is discharged through holes in the bottom of the trough. The hole opening may be controlled by an adjustable slide.

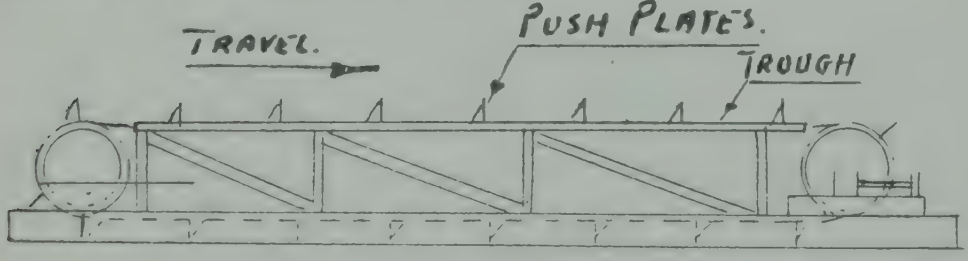


Fig. 69. Scraper Conveyor

SCRAPER CONVEYORS.—In this conveyor, scraper plates are traversed through a rectangular shaped trough by endless chains mounted on sprockets at either end of the trough. The scrapers may be mounted between two chains or, alternatively, may be carried by one central chain (Fig. 69).

DRAG LINK CONVEYORS.—Drag link conveyors exploit the carrying capacity of special shaped links travelling in rectangular or circular cross section boxes. The action is carrying, not pushing as in the scraper conveyor. The chains are mounted in terminal sprockets, one of which is driven, and the other adjustable, to correct working tension.

GRAVITY BUCKET CONVEYORS.—This handling device is commonly a combined elevator and conveyor. Conveyor buckets of special design are swung between two endless chains. The

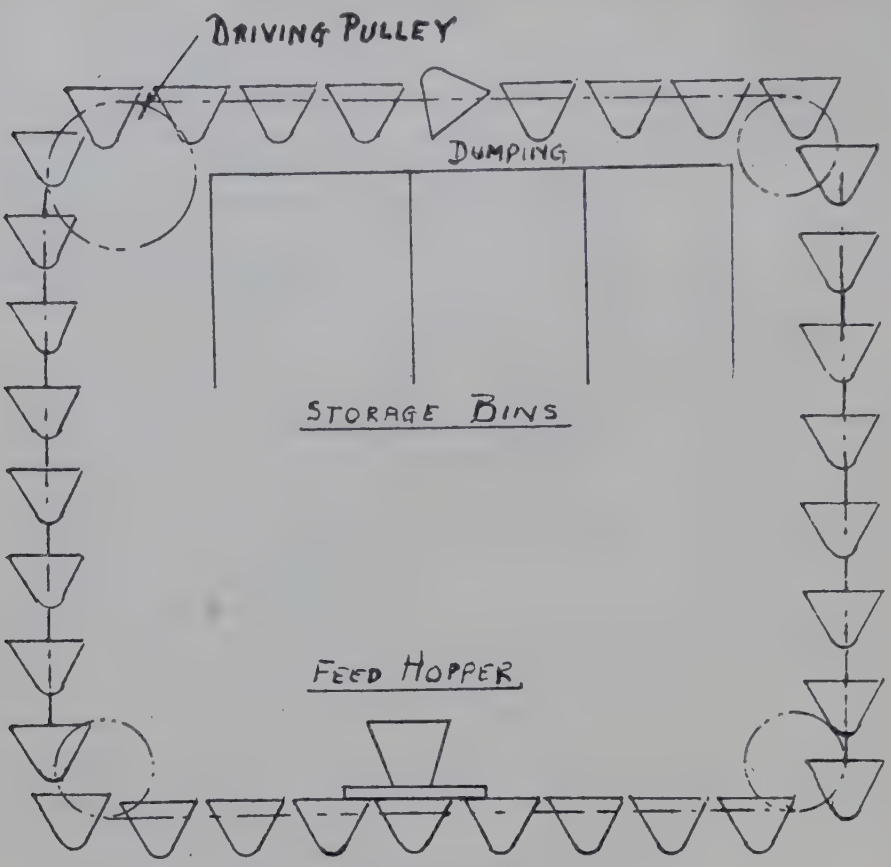


Fig. 70. Gravity Bucket Conveyor

chains often traverse the elevation perimeter of a nest of bins, being carried on four sets of sprockets (Fig. 70). The buckets which are usually filled at the bottom of the elevating leg, tip their contents at some predetermined point by the action of a cam, or tripper, mounted on the conveyor rack, and arranged to interfere with a corresponding cam on the buckets.

Storing of Bagged Materials

A number of the materials which arrive at the mill in bags are emptied therefrom and stored in bulk. Some of these materials are not of a convenient particle size when received, and need to be broken or kibbled before they can be handled satisfactorily by the bulk handling plant.

Kibbling may be done in several kinds of machines, amongst which is found the Nicholson, or Hercules type breaker. This machine is considered here because, in compound mills, it is used for kibbling purposes only, whilst other grinders, such as the swing hammer type which may be used for kibbling, are also used for process grinding, and will be considered under Grinding Machines.

The Nicholson breaker may consist of one, two or three pair of toothed rollers, the pairs being mounted one above the

other. The top rolls have the coarsest teeth, the bottom rolls, the finest.

The rolls are made up of a number of wheels having diamond shaped teeth and separated one from another by distance rings wide enough to allow the teeth of one roll to run between the teeth of its mate. The wheels and distance rings have a square hole through the centre, through which is threaded a square shaft. The shaft is turned at each end to fit into bearings mounted in cast iron or fabricated steel cheeks. The rolls are geared together to give differential speeds, and to permit a set being driven from one driven shaft. Each roll runs in the opposite direction to its mate.

BAGGED MATERIALS which are to be stored in the bags they are received in need little comment at this stage.

The piling of bags involves a lot of manual labour. The incidence of portable bag stackers has reduced this, but bag handling still involves considerable labour costs, and the chief bag conveyor inside the mill is still the common truck.

CHAPTER VI.

GRINDING MACHINERY

The importance of the size and shape of the compound millers' raw materials is well illustrated by the vast amount of machinery that is used to alter these characteristics.

It is true that many grinding machines, particularly in the provender mill, are used to release the contents of grain, or to enable the parts of the grain to be separated, or to alter the texture, but the fact remains that the largest part of the grinding machinery used in the feeding stuffs industry is occupied in the alteration of particle size and shape as a primary objective.

Handling, storage, mixing, cubing—all these functions are expedited by having the most suitable particle size of raw material. To consider an absurd case, it would obviously be impossible to obtain a homogeneous mixture of slab oil cake, original locust and oats, but after reduction to meal form, the proposition is a very practical one.

Machines for size reduction may be divided into different classes, and each class may contain many members, but for our purpose, we shall confine our attention to :

(a) Roller mills.
(b) Mill stones.
(c) Impact machines.
(d) Cutters.

ROLLER MILLS are more frequently found in provender mills than compound mills, for the method of reduction does

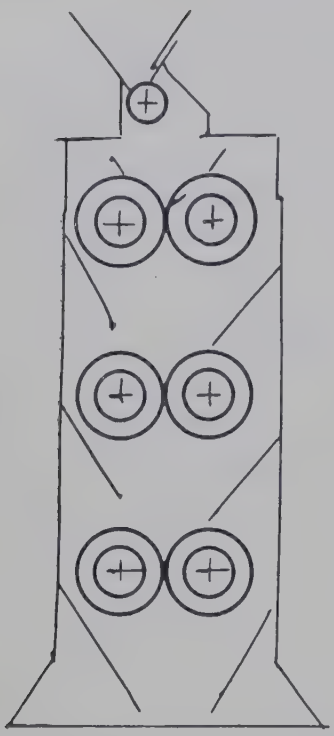


Fig. 71. Horizontal Roller Mill

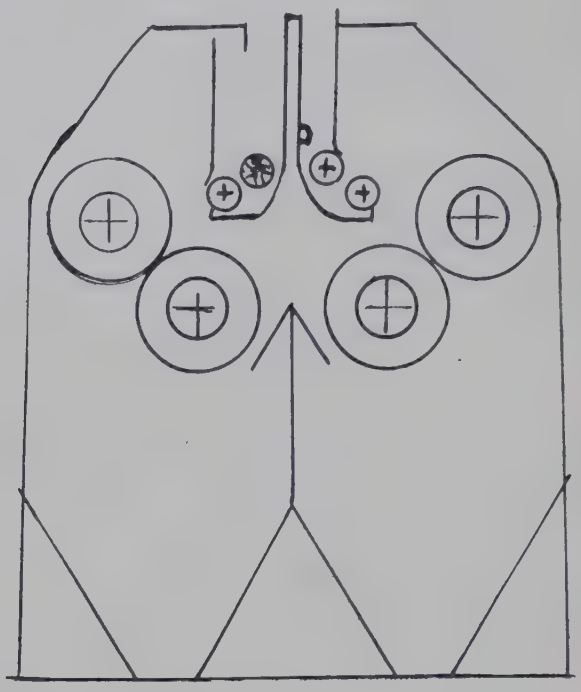


Fig. 72. Diagonal Roller Mill

not make any one size of roll suitable to a wide range of particle size in the feed, but for materials whose particle sizes only vary within narrow limits, like maize or wheat or oats, a good roller mill is an effective reducing machine.

The usual type of roller mill found in the feeding stuffs industry is very similar to, and, in many cases, identical with those used in the flour milling industry. The reduction of the fed material is obtained by introducing it between two fluted, chilled iron rolls which are revolving in opposite directions at different speeds. The flutes of the rolls are cut in a slow spiral along the length of the roll, the slower running roll of a pair has the sharp edge of the flutes following.

The speed of rolls, position of cutting edge, spiral, shape of tooth, number of teeth, are open to many modifications, and different millers often put their faith in different arrangements.

Once the above factors are decided, the machines carrying the rolls exhibit a fair degree of unanimity in design. The two types commonly used are the diagonal rolls and the horizontal rolls. The terms diagonal and horizontal, refer to the position of the common centre line of a pair of rolls.

Horizontal and diagonal reducing rolls are illustrated in Fig. 71 and Fig. 72.

Common features of both types are:

(1) A roll feeding device to ensure an even supply of material over the length of the breaking roll.

(2) Spring loading of one or both rolls of a pair, to reduce the damage which the passage of foreign matter might cause.
(3) Adjustment for position of rolls.
(4) Means of preventing roll faces rubbing together.

MILL STONES.—In this class of grinding machine, we become acquainted with the forerunner of all reduction mills, but its importance to us, as compound millers, is not very great. The fundamental principle is, of course, the rubbing of the grain between two specially prepared stone faces, but the practice of cutting furrows tends to impose a shearing action

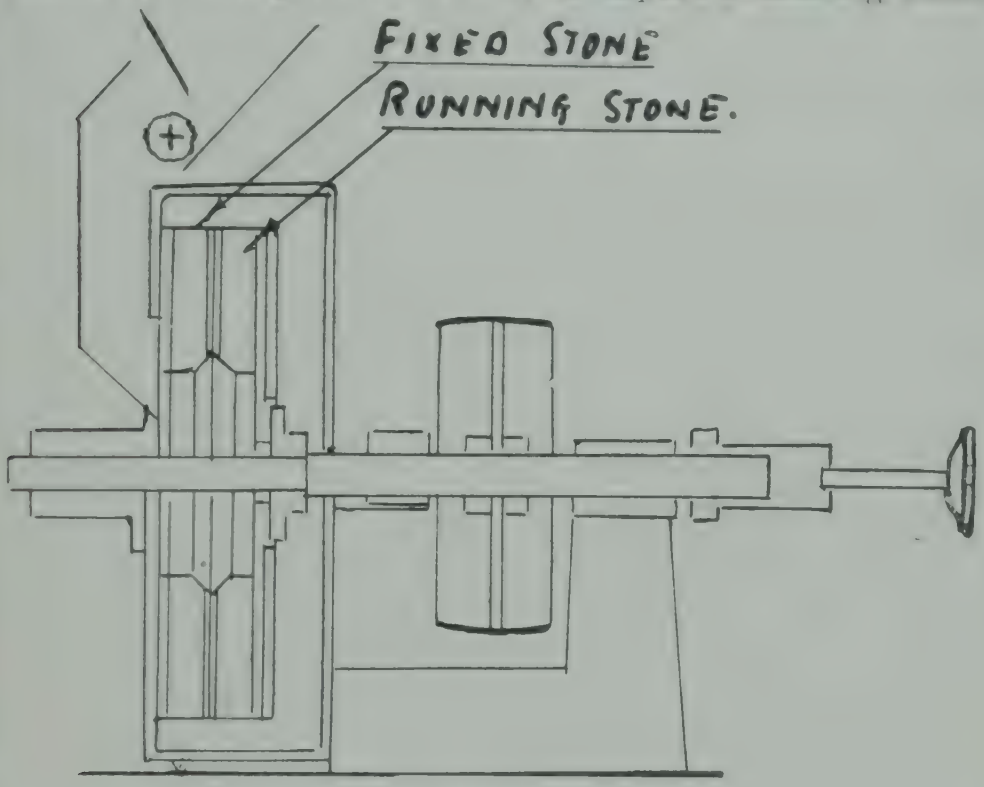


Fig. 73. Vertical Stone Grinder

upon the grain. It is convenient to have the faces circular, to help to convey the material between the stones by revolving one or both of the stones.

The commonest arrangement is to have one stone stationary and the other revolving, the circular faces of both stones being horizontal. Several advantages accrue from having the bottom stone revolving, such as the elimination of the effect of the stone's own weight on the application of grinding pressure, and also a larger capacity, due to the better centrifugal action speeding up the flow of grain through the mill.

A common feature of mill stones is the furrows which are cut in the working faces. These furrows take the form of channels which may vary considerably in size and shape. For wheat, the grooves are 2 ins. wide × one-quarter inch thick.

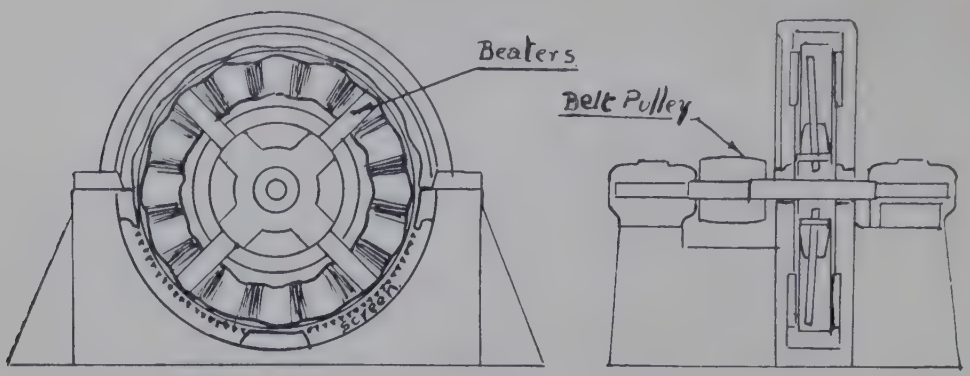


Fig. 74. Fixed Beater Grinder

The area of stone between grooves or furrows is known as the land, and is that part of the stone which forms the reducing or grinding area.

The purpose of furrows is to assist the distribution of the feed and to keep the job cool, but they also provide cutting edges.

The draft of a furrow is the eccentricity of the furrow with the eye of the stone. The eye of a stone is the central hole through which the stones are fed.

When considered against the long history of mill stones it is only comparatively recently that fan exhaust systems have been applied to them. The result of this has been increased output, cooler grinding and, very often, an improved product.

A more modern design of stone mill has the stone revolving in a vertical plane about a horizontal axis, and in spite of the

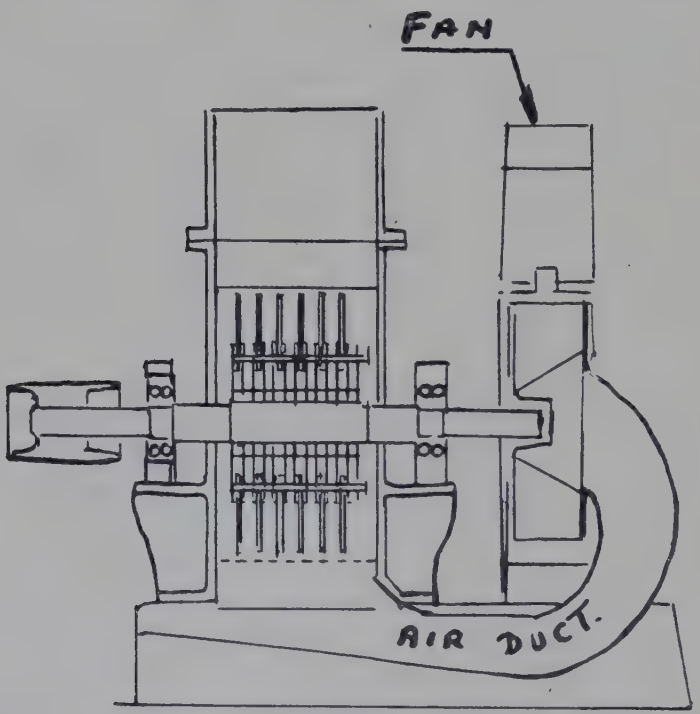


Fig. 75. Swing Beater Grinder with Fan Exhaust

criticism that this results in an uneven distribution of the wear on the stones, the advantages of the arrangement, such as more convenient feed, better driving conditions, and greater output, have firmly established a place for the machine in the milling industry (Fig. 73).

A further development was the introduction of metal disc grinders, one type of "mill" having one stationary and one revolving disc. The plane of rotation is vertical, the discs have the working clearance between them controlled by a spring and screw arrangement.

There are also a number of metal disc grinders which have both discs running in opposite directions. The discs of these grinders are so shaped that the action is not wholly attrition, a fair proportion of the grinding being the result of impact action between disc and disc.

IMPACT OR PERCUSSION GRINDERS.—Here, the material to be ground is pulverized by blows from high-speed beaters, and reaction blows from fixed breaking surfaces. The beaters take many forms: in one machine, they are steel pins fastened to the face of a revolving disc; in another machine, they are rectangular slabs pivoted between the discs of a centre rotor.

The family of percussion grinders may be classified in a number of ways, such as slow, medium, and high speed, or as fixed beater and swinging beater, or again, as fine grinders, and coarse grinders. A useful method of classification is to consider individual machines of the family as falling into one of the following three groups:

1. Those with rigid beaters that reduce the material in a single stage.
2. Those with rigid beaters that reduce the material in two or more stages.
3. Those with pivoted beaters which are free to swing in the plane of rotation.

The first class of machine is chiefly represented by the grinder that has four fixed beaters rotating in a chamber, with a screen for half the periphery, breaker plates for the other half, and wave form plates for the sides (Fig. 74).

The beaters often are all part of a common forging, with a boss keyed to the shaft. The wave form plates may be in sections, and are bolted to the inside of the main chamber casting. The breaker plates and screens are both easily renewable. Modern machines are fitted with bearings of the ball and roller type, although some machines of the low and medium speed class still run in ring, self oiling bearings.

The second class of impact machines has a number of representatives, one of which is the grinder having two discs fitted with beater pins. One of the discs is stationary, and the other revolving. Material to be ground is fed into the centre of the

fixed disc, and is conveyed between the rows of pins by both the centrifugal and fan action of the machine. Having passed the last row of pins, the exit of the material from the grinding chamber is controlled by a peripheral screen. Another member of this family is a grinder in which the preliminary breaking is done by an inner row of beaters surrounded by a circle of fixed pins, and the final grinding is carried out by beaters traversing the outer annular chamber whose sides are corrugated, and whose periphery is formed by a perforated or bar screen.

The third class of machine, usually referred to as the hammer mill, has very many representatives, but the essential feature is the freedom of the revolving beaters to swing in a limited arc about their own pivots (Fig. 75). The rotor carrying the beaters, or hammers, is built up of a central shaft to which is fitted comparatively thin discs, separated axially sufficiently to allow the beaters to be mounted between them upon pins which commonly pass through all the discs, near their outer edge.

Speeds of hammer mills are usually high, varying from 2,000 to 5,000 revolutions per minute. The grinding chamber may be formed completely of perforated or bar screens, or part of the chamber may consist of breaker blocks, against which the material is thrown by the action of the hammers. Unlike the previous class of machine, material is fed to hammer mills at a point on the periphery.

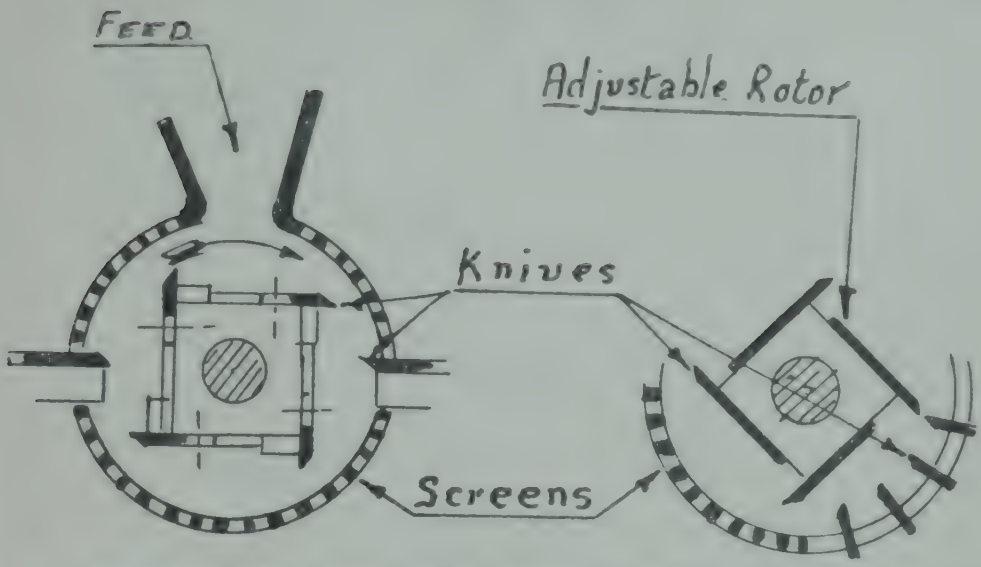
In all three classes of grinders, the machine may be fan exhausted, and, in some instances, the fan is used to convey the material from the grinder to a sacking off point located a considerable distance away.

CORN CUTTERS are used chiefly for the splitting of maize into two, three or more pieces in the production of corn grits. A shaft carrying cutters, or knives, revolves between fixed knives mounted inside a cylindrical chamber. The wall of the cylinder is mainly composed of a perforated plate screen, the size of whose perforations determine the size of the grits leaving the chamber.

In one make of machine, the fixed knives are located at opposite ends of the horizontal diameter (Fig. 76), whilst in another make, they are located in one of the lower quadrants of the chamber (Fig. 77).

The second machine has a rotor whose position can be altered by a screw lever mechanism, allowing the clearance between the cutting edges to be adjusted without opening the machine. Corn cutters are frequently mounted over an oscillating grading screen, which may be fitted with an aspirating fan.

With the exception of corn cutters, which produce a finished article, the grinding machines referred to are mainly used in compound milling for the preparation of the raw materials for



Figs. 76 and 77. Corn Cutters, showing Cutters and Screens

the mixing or blending processes from which the mill takes its name.

CHAPTER VII.

PLANT RELATIONSHIPS

Before passing on to the consideration of mixing, it is perhaps advisable to consider briefly the relationships existing between the items of plant referred to since the commencement of the course. A convenient way of doing this is to draw up what is called a flow sheet.

The purpose of a flow sheet, as its name suggests, is to show the path of the materials through a plant, or section of a plant. This could be done by making an architect's or engineer's drawing of the mill, a process which would take a long time, and except with the simplest of arrangements, would require a considerable amount of experience to interpret. The other extreme would be to write out a list of machines in the order in which the materials ran through them.

For broad generalization, this might be satisfactory, but any indication of individual items of plant might involve lengthy written descriptions which would tell against a quick reading of the flow sheets. What is needed, is a method of representing a process which is both easy to construct and clear to read, and which tends to create a composite image of a whole process in the mind of the observer.

This is achieved, to a great extent, by using easily drawn conventional symbols to represent items of plant and machinery.

Some industries, like flour milling, have a large number of accepted symbols in common use, but variations are observable in the designs coming from different draughtsmen. It should be noted, that whilst a language may display character and colour in a variety of words having the same meaning, nothing

but confusion can arise from the use of different flow sheet symbols to represent the same thing.

As far as the writer is aware, there is no comprehensive list of accepted symbols in use in the feeding stuffs industry, but many symbols in use in other industries will serve in the compound and provender milling flow sheets, and typical examples are shown in Fig. 78 and Fig. 79.

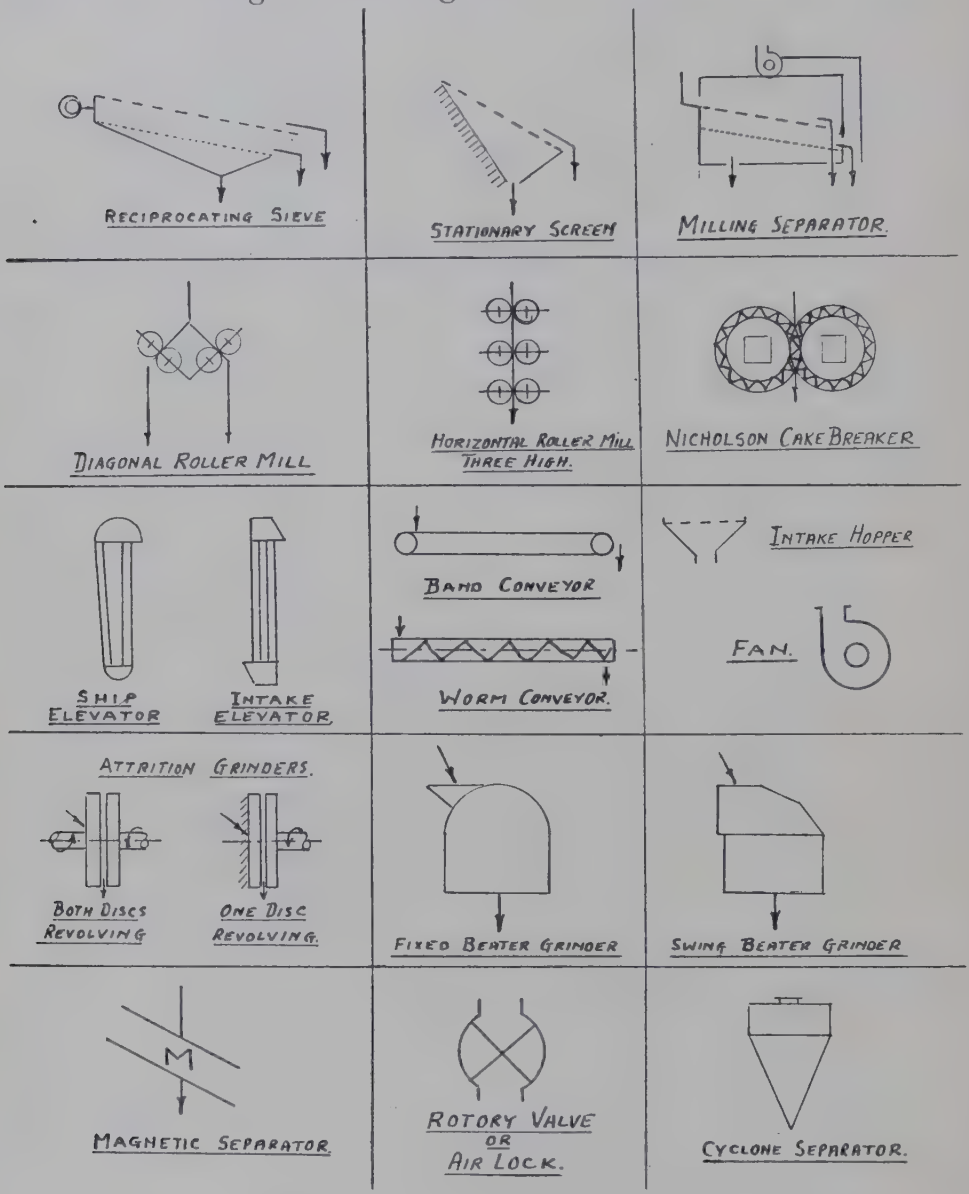


Fig. 78. Flow Sheet Symbols

The examples shown include elevators and conveyors, although, in general, the movement of a material from one point to another is shown on a flow sheet by a plain line with an arrowhead indicating the direction of the flow. Alternative routes to main runs are often shown as dotted, or chain lines, but where more detailed information is required, the handling machines are indicated by their appropriate symbols.

A typical intake flow sheet might be drawn as Fig. 79.

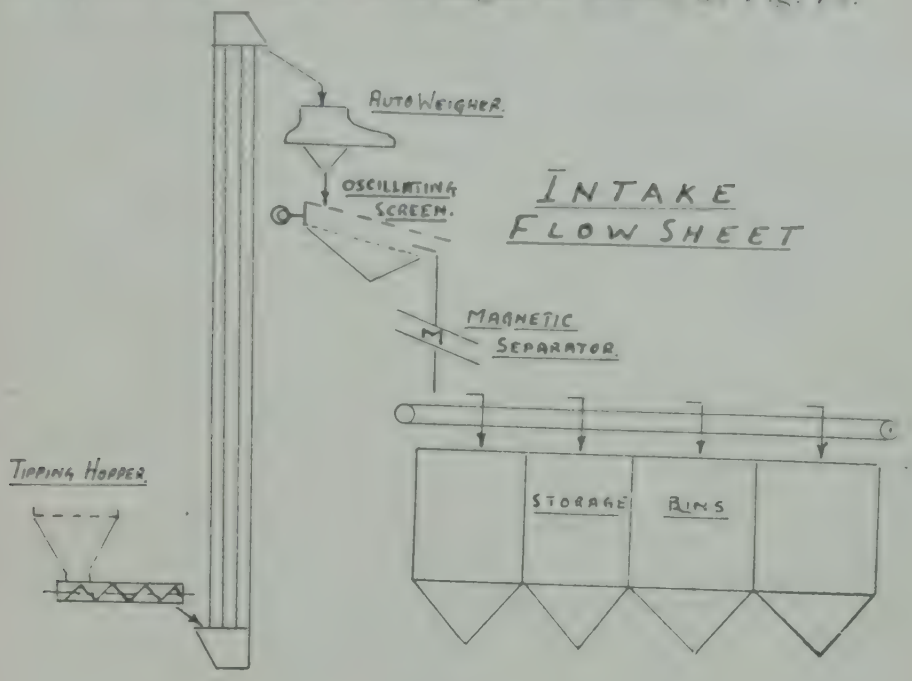


Fig. 79

CHAPTER VIII.

MIXERS

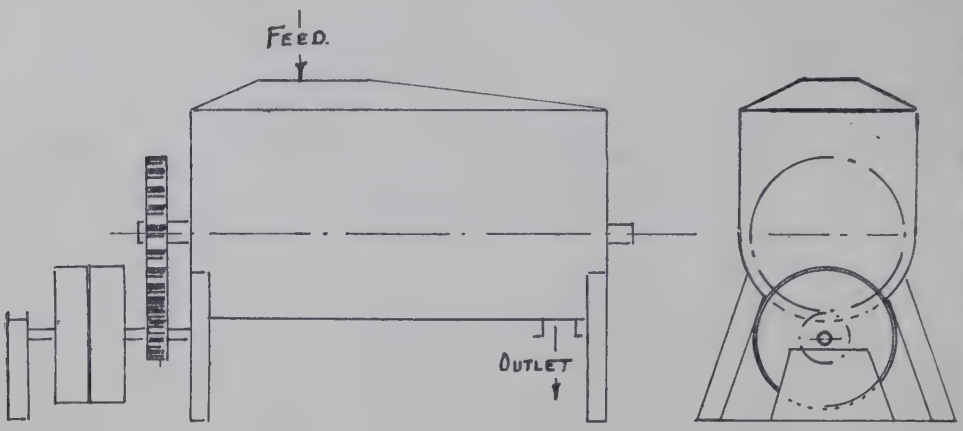
Mixing is the process of blending two or more ingredients into an homogeneous whole. If, for instance, a ton of mixed meal contains two parts of groundnut cake meal, and one part of maize meal, then every ounce of that ton should contain two parts of groundnut meal and one part of maize meal. The ease with which materials can be mixed together thoroughly depends upon :

(1) The variation in particle size of the ingredients.
(2) The variation in specific gravity of the ingredients.
(3) The number of ingredients.
(4) The dampness or stickyness of the ingredients.
(5) The time available per unit weight of mixing.
(6) The range of proportions of the ingredients.

A wide range of machines is available from which a choice may be made. The simplest form of mixer is the cylindrical pan or kettle having a horizontal stirrer fastened to a rotating vertical shaft. The face of the stirrer may be set at an angle to give the ingredients a slight lifting, as well as a rotating action.

Horizontal "U" Trough Mixer.—A "U" shaped cast-iron or fabricated steel trough carries a shaft to which are fastened special ribbon worm blades, some of which act in the opposite direction to the rest of the blades (Fig. 80).

Vertical Archimedian Mixer.—This consists of a vertical cylinder having a hoppered bottom with a central vertical shaft



HORIZONTAL TROUGH MIXER

Fig. 80

carrying a continuous spiral worm. The worm lifts the centre core of material and causes a flow as indicated by the arrows in Fig. 81.

SPRAY MIXER.—Consists of a cylindrical flat-bottomed pan with a central vertical shaft, and a vertical worm conveyor fastened to the outside of the pan. The bottom of the pan, which is swept by a stirrer, contains an outlet hole controlled by a slide, and another hole communicating with the trough of the vertical worm conveyor. The pan itself is divided near the top by a horizontal perforated plate which is swept by a stirrer attached to the central shaft.

Material being mixed in this machine is circulated from the bottom of the pan to the top by the worm conveyor, and is returned to the bottom of the pan by the action of the top stirrer sweeping it through the slots in the dividing plate. When the mixing is complete, the material flows from the pan by opening the slide controlling the discharge outlet (Fig. 82).

GLOBE MIXER.—Special shaped stirrer blades fastened to a horizontal shaft rotate in a hemispherical vessel. The bottom of the vessel has a discharge outlet.

DRUM MIXER.—A horizontal drum rotates on a fixed shaft. Stirrers are fitted to both drum and shaft. The machine is fed and emptied through a door located in the wall of the drum.

CASCADE MIXER.—A mixing box, or trough, carries a horizontal shaft to which blades are fitted, so that whilst there is a certain amount of backwards and forwards movement of the material, the main flow is towards the outlet end.

DUPLEX MIXER.—Two worm troughs, each with its own worms, are joined Siamese fashion, and as the worms revolve in opposite directions, the materials in each trough are thrown together and conveyed from one end to the other. The worm blades are adjustable, so that the travel of the meals being mixed can be made subject to a variety of rates of flow.

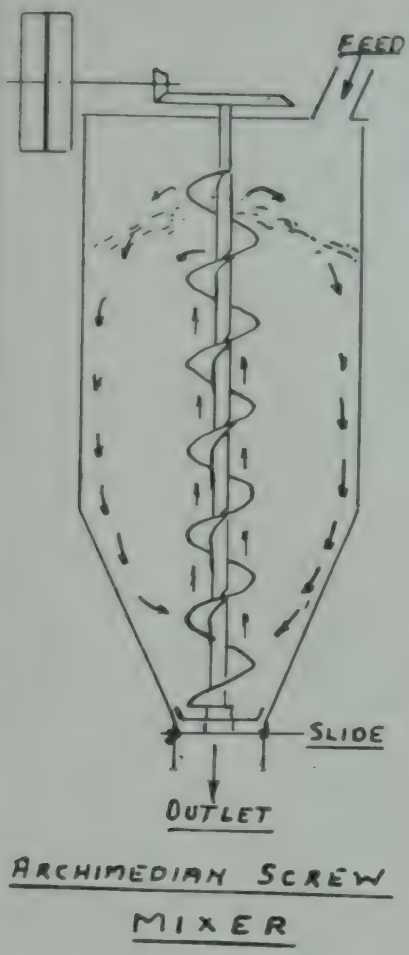


Fig. 81

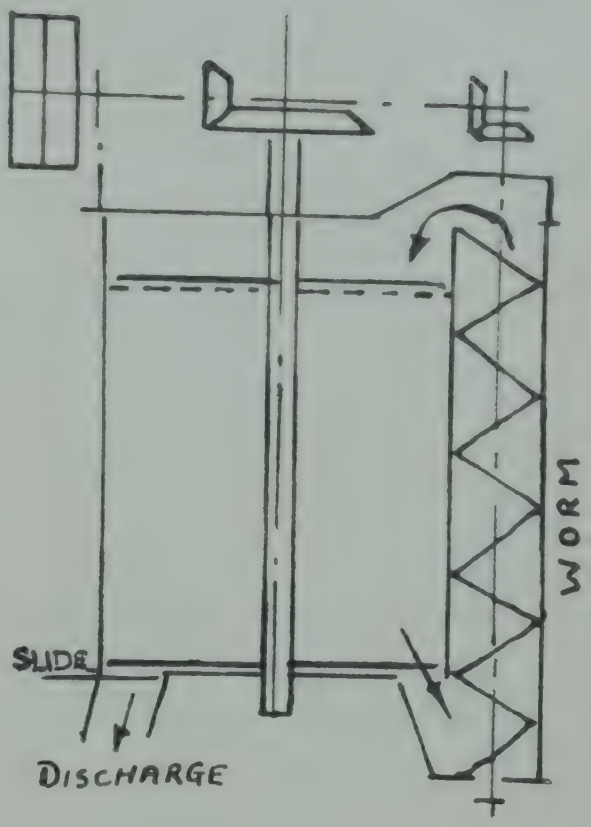


Fig. 82. Spray Mixer

Of the foregoing mixers, the simple kettle, the Cascade, and the Duplex mixers are suitable for continuous operation, the remainder working upon the batch principle.

Continuous mixers must have the ingredients fed to them in coincidental streams. Batch mixers may be fed with a consecutive flow of materials.

Molasses Mixers

Originally, molasses was introduced into a meal through a perforated pipe located above the cooker or kettle, the flow being regulated by the manual operation of a cock in the pipe line. In almost every case, the molasses gravitated to the kettle from an elevated pilot tank into which it had been previously pumped. The molasses would be warmed to facilitate pumping and mixing.

Various devices have since been introduced to eliminate the constant supervision required by the old method, and also to link up the molasses supply with the meal supply. Some of the molasses measurers feed definite weights of molasses, others control the volume at fixed temperatures.

The intimacy of mixing of the meal and molasses has also received a fair amount of attention, and alternatives to the simple kettle with stirrers are offered in the form of the globular mixer with the molasses fed in a large number of tiny streams, the cascade mixer incorporating a steam operated atomising sprayer, and one or two variants of these devices.

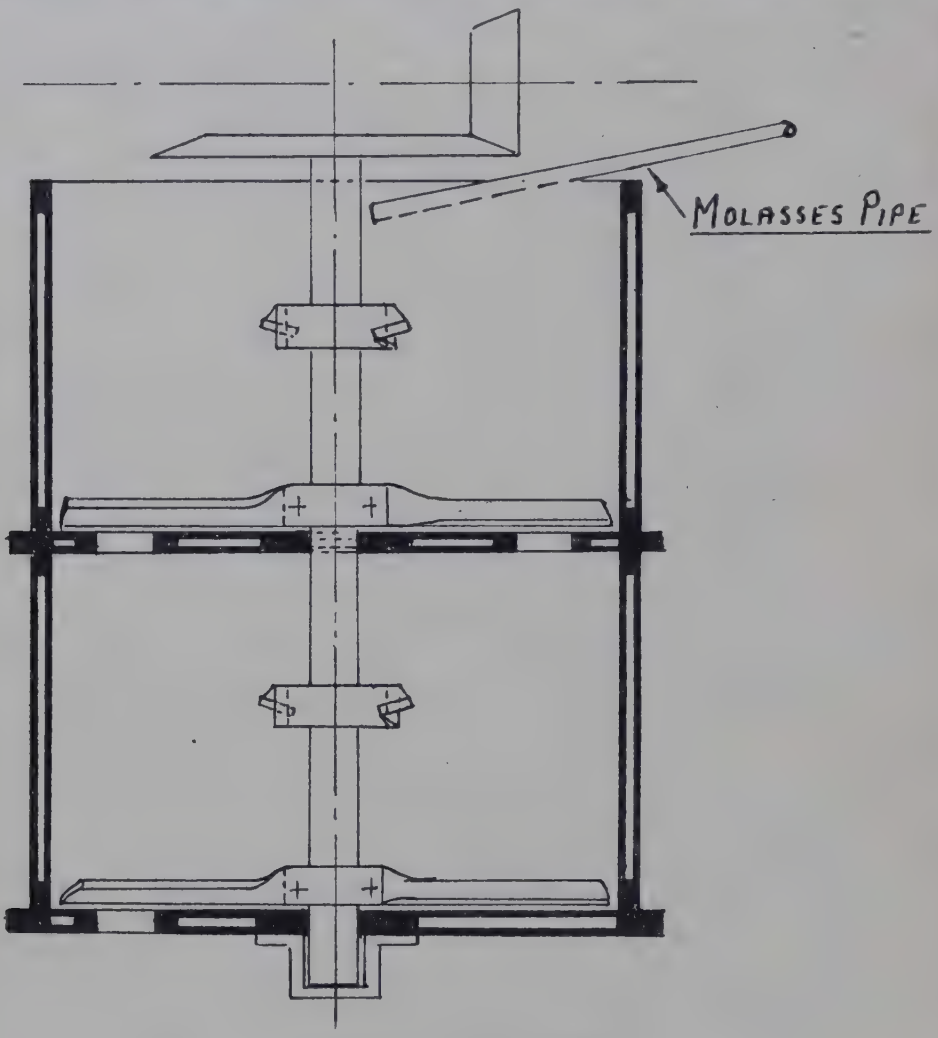


Fig. 83. Two High Jacketted Kettle

An outline of a simple steam jacketted cooker or kettle is shown in Fig. 83. It should be noted that it may take twenty minutes from the time the meal enters the top of the kettle to the time when it leaves the discharge outlet, whereas, in a mixer of the cascade type, the meal may pass right through the machine in little more than one minute.

Feeding of Mixing Plant

Mixing machines may be fed from a hopper into which the ingredients are tipped by manual labour, or alternatively, the mixer may be part of an automatic mechanical mixing plant incorporating a number of proportioning feeders or automatic weighers.

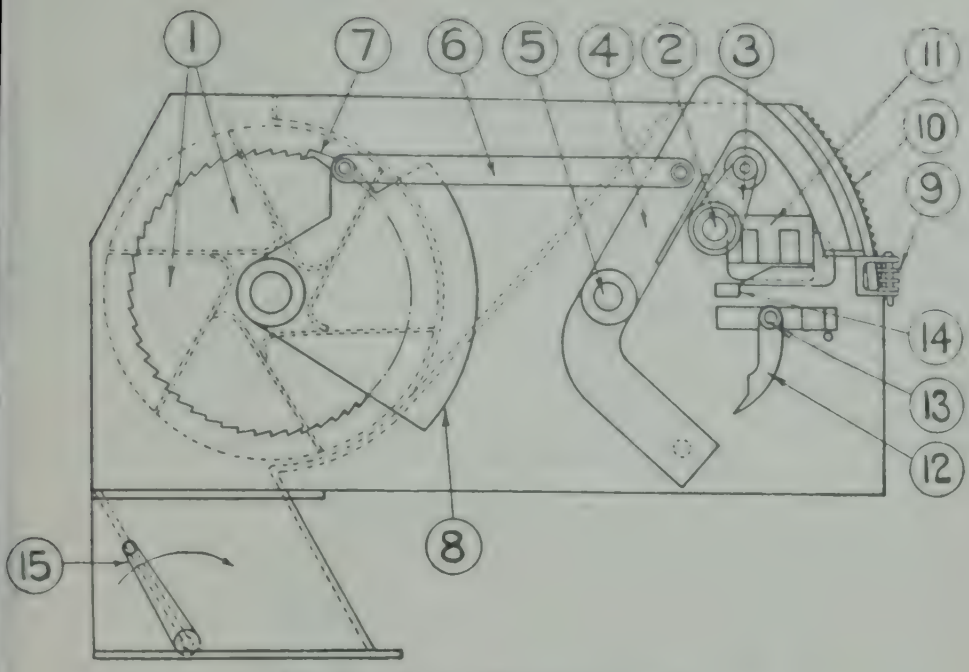


Fig. 84. Simon Measurer Feeder

(1) Pocketted Drum, (2) Driving Shaft, (3) Driving Cam, (4) Rocker Arm, (5) Rocker Arm Pivot, (6) Push Rod, (7) Pawl, (8) Pawl Counter Weight, (9) and (10) Capacity Regulator, (11), (12), (13), (14), Remote Control Mechanism, (15) Sampling Flap.

In the manually fed plant, a tipping hopper fixed in the mixing floor, or suspended on the beam of a dial scale, is filled with the ingredients to be mixed.

In the first case, as soon as the hopper is full, the slide in the discharge spout is drawn and the meals begin to flow out into either a continuous mixer, in which case the hopper is charged continually, or, with a batch mixer, the charge in the hopper is allowed to drop into the mixer, and the outlet slide closed before refilling of the hopper commences.

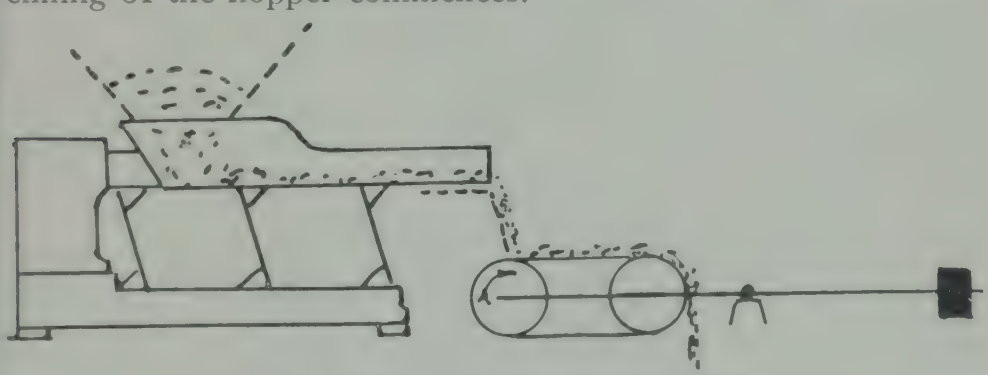


Fig. 85. Electric Vibrating Feeder Weigher

With the second arrangement, the ingredients are measured into the scale hopper by the weight readings marked on the dial. The dial may be fitted with adjustable markers to indicate the required proportions of the ingredients. As soon as the full

weighment has been obtained and the mixer has discharged i previous weighment, the scale hopper gate is opened, allowi the contents of the hopper to be fed into the mixer.

In the mechanically operated automatic mixing plant, it necessary that a nest of pre-mixing bins be filled with the i gredients from which the compound food is to be manufacture At the outlet of each bin is fitted a mechanical feeder, or a automatic weigher. The feeders or weighers are adjusted t deliver the correct amounts of the ingredients simultaneousl An alternative arrangement uses a smaller number of portabl indicating weighers, each running on rails underneath a line o bins, but whilst this effects an undoubted economy in capita expenditure, it tends to increase the working cost of mixing.

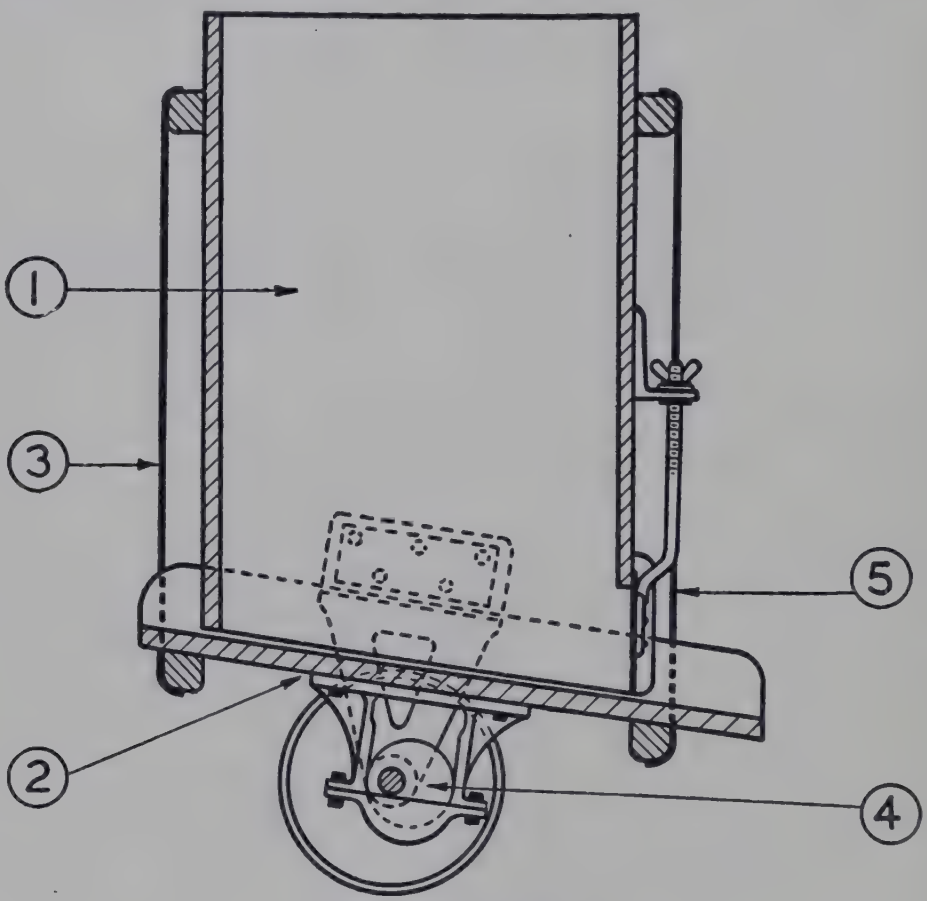


Fig. 86. Shoe Feeder

(1) Feed Box or Bin Bottom, (2) Oscillating Shoe, (3) Flat Springs, (4) Eccentric, (5) Control Slide.

Typical volumetric feeding devices are:

THE SMITH FEEDER, in which the screw of a short worm conveyor is driven through a pawl and ratchet mechanism, which can be adjusted to alter the rate of feed. A graduated scale is incorporated which allows particular settings to be repeated. The double ratchet version of this feeder allows a range of adjustment of thirty times the minimum quantity.

EXACT MEASURER, which consists of a radial bladed rotor running in a housing, after the manner of a rotary air seal, and arranged that one of the end plates is capable of axial movement, thus allowing the pockets formed by the radial blades to be increased or diminished. In practice, the rotor and the chamber in which it revolves are usually divided in two by a central partition, and both end plates of the rotor are adjustable. The adjustment can be made whilst the measurer is in operation.

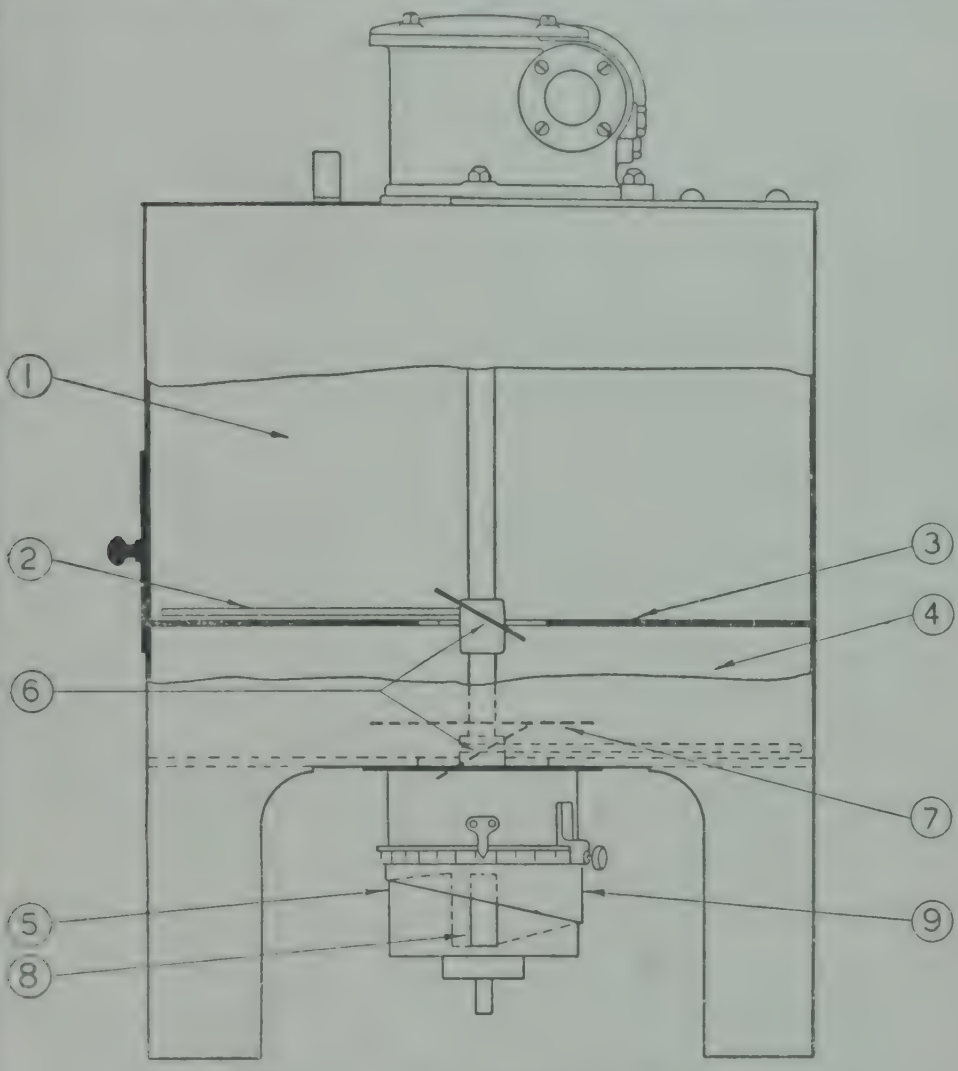


Fig. 87. Simon Mechanical Feeder

(1) Receiving Chamber, (2) Revolving Stirrer, (3) Partition Plate, (4) Lower Chamber, (5) Feeding Cylinder, (6) Lifters, (7) Baffle and Pressure Plate, (8) Discharge Slot, (9) Control Sleeve.

SIMON MEASURER FEEDER.—In this device, shown in Fig 84, a drum, having a number of compartments giving the effect of elevator buckets joined together round a common shaft, is revolved through a ratchet and pawl mechanism. The movement of the pawl can be varied by adjustment of the intermittent motion mechanism, which allows a range of adjustment of thirty times the minimum quantity.

ELECTRIC VIBRATING FEEDER.—In this modern device, a feed shoe or a tray is oscillated through a very small travel at a very high rate of oscillation by an electro-magnetic vibrating motor. The feed drops from the tray on to a short band conveyor which is carried on one end of a sensitive balance. The weight of material being discharged is kept constant by the governing action of a device known as an electric brain which, upon the weigh scale registering any out of balance, slows down or speeds up the vibratory motor (Fig. 85).

SHOE OR SHAKER FEEDER.—A very popular feeding device which is hardly entitled to the name measurer. Tray suspended on flat springs under the bottom of a bin. An oscillating motion is imparted through a simple eccentric. A rough control of flow is obtained by operating a slide, usually through a rack and pinion mechanism (Fig. 86).

SIMON MECHANICAL FEEDER.—This measurer is intended for the very accurate feeding of those dry, powdery materials which are mixed into compounds in small quantities. A cylindrical pan, divided into two compartments by a horizontal plate, has a central vertical shaft extended into a small cylinder fastened under the bottom plate. Both the division plate and the bottom plate contain a hole at the centre, through which the material is swept by stirrers attached to the shaft. A short distance above the hole in the bottom plate, a baffle keeps the weight of the bulk off the material flowing into the small cylinder underneath.

The flow of material from the small cylinder which takes place through a vertical slot in the wall is controlled by varying the size of the slot by the movement of an obliquely cut sleeve. The movement of the sleeve is measured on a graduated scale (Fig. 87).

CHAPTER IX.

CUBING PLANT

The compound cube has long been recognized both as a convenient and efficient form of food for feeding livestock. Originally, compound cakes were manufactured in hydraulic presses, but with the advent of the continuous cubing machine, the presses rapidly fell into disuse. The original continuous cubing machine was a screw machine, in which a robust worm or screw operating in a cylinder conveyed meal from one end of the cylinder to the other, and discharged it under pressure through holes in a die plate which formed the discharge end of the cylinder.

It may be noted here, that cubing machines fall into two

broad classifications as extrusion machines and moulding machines. The worm or screw type cubing machine is an extrusion machine, in that the compressed meal is extruded in continuous streams and cut off into cube lengths by a knife. The moulding machine in which each cube is compressed individually is typified by the Marshall machine, in which two short, large diameter cylinders, having indented surfaces, are revolved together in opposite directions, and are so synchronized and mated that the projections in each cylinder together form a complete closure for the pockets of meal being compressed between them.

Generally speaking, the product of a moulding machine has a more pleasing appearance than that of the extrusion machine, but the extrusion principle lends itself so readily to the manufacture of cubes that many representatives of this class are available.

Typical examples of the extrusion machine are the:

Orbit of Messrs. Richard Sizer Ltd.
Porteus machine of Messrs. George Porteus Ltd.
Californian Press of Messrs. Henry Simon Ltd.
Pelcub of Messrs. Richard Sizer Ltd.
Swashplate type machine.

ORBIT.—In this machine, the meal is fed between the inner face of a die ring and an internal roller, in such a manner that it is extruded from the outside face of the die ring in sticks having the same cross sections as the holes in the die. The lengths of compressed meal are cut to cube size by the action of a fixed knife.

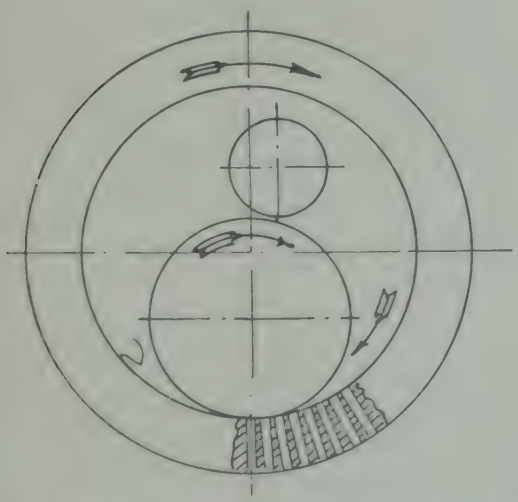


Fig. 88. Orbit Cubing Machine

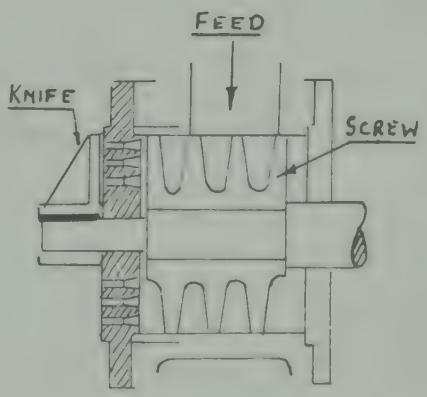


Fig. 89. Screw Type Cubing Machine

PORTEUS.—The dies are made in the form of spur tooth gear wheels. The holes through which the meal is pressed are located between the roots of the gear teeth and pass through the rim of the wheels. The meal to be compressed is fed into

the nip of the gears and is extruded from the inside of the rims where it is cut by fixed knives.

SWASHPLATE TYPE.—The action of this machine is obtained by running a circular die plate against a circular compression drum whose axis of rotation is set at an angle to the axis of the die plate. The inclination of the axes is such, that whilst the plates are in contact at the bottom of their path, there is a gap between them at the top. Meal is fed into the gap, and being carried round by the plates, is extruded through the die plate by the moving together of the two plate faces at the bottom of their path.

CALIFORNIAN PRESS has a horizontal fixed die plate, with its top face traversed by four compression rollers, and its under face traversed by one, two, or four knives.

PELCUB.—Operating principle is similar to that of the Californian Press, but the die plate of this machine is not fixed; it revolves in the opposite direction to that of the knives and rollers.

Both the Californian Press and the Pelcub are edge runner type machines.

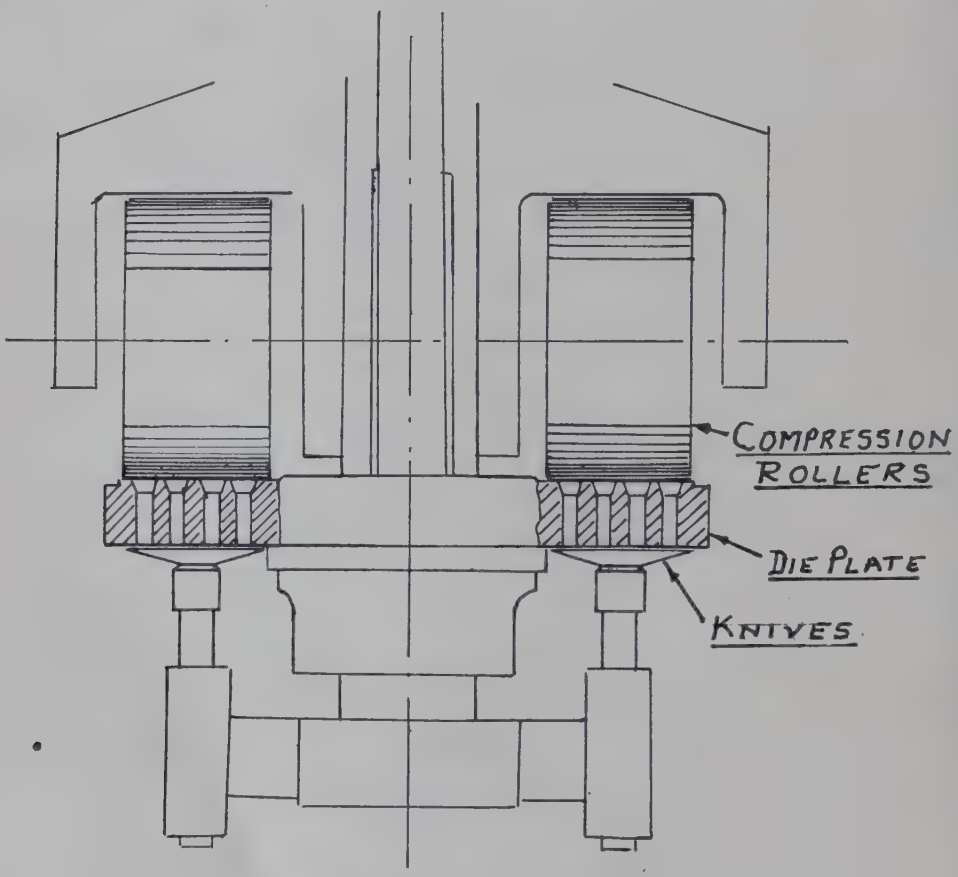


Fig. 90. Edge Runner Type Cubing Machine

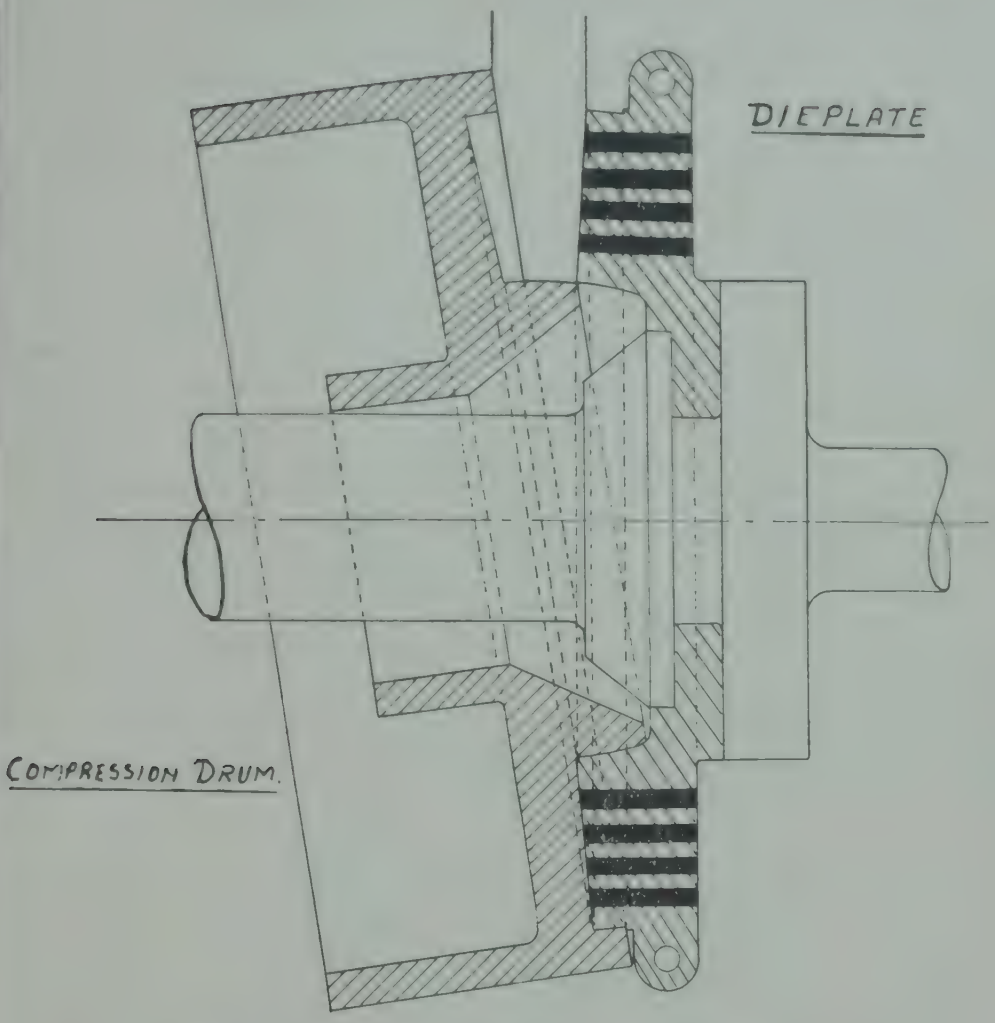


Fig. 91. Swashplate Type Cubing Machine

CUBE COOLERS.—Compound cubes are nearly always discharged from the cubing machine at temperatures higher than that at which they may be safely bagged. It follows, therefore, that the cubes must be cooled to a temperature at which they will keep in good condition for a considerable period of time when stored in bags.

Cooling, like all the other compound milling processes, is carried out in a variety of apparatus. The common feature of most coolers is the use of air currents to cool the cubes. One of the critical factors affecting cooler design is the necessity for maintaining the cubes in contact with the cooling air for a certain minimum period of time.

The actual period of time appears to vary somewhat with the working conditions and the design of cooler. In this respect some authorities suggest that the cubes should be cooled to atmospheric temperature, and that they should be in the cooling air for at least an hour. To be compared with this, is a machine which, to the writer's knowledge, satisfactorily

cools the cubes in as short a time as eight minutes. It is suggested by this that there are a number of variable factors in the process of cooling, which will need consideration later on in this course. For the present, it is sufficient to be aware of some of the machines that are, or have been used to cool cubes.

A distinction may be drawn between those machines in which the cubes are conveyed through the cooler, and the coolers through which the cubes gravitate. In both classes, the cooling air may be blown or drawn through the cube, or it may be both blown and drawn in a balanced draught system.

One type of cooler through which the cubes gravitate is not unlike a cyclone in appearance except that there are gaps in the walls through which most of the cooling air is drawn.

A sectional illustration of this apparatus is shown in Fig. 92.

The cubes are fed in at the top and are spread by the internal cone. This cone surmounts a system of ducting which collects

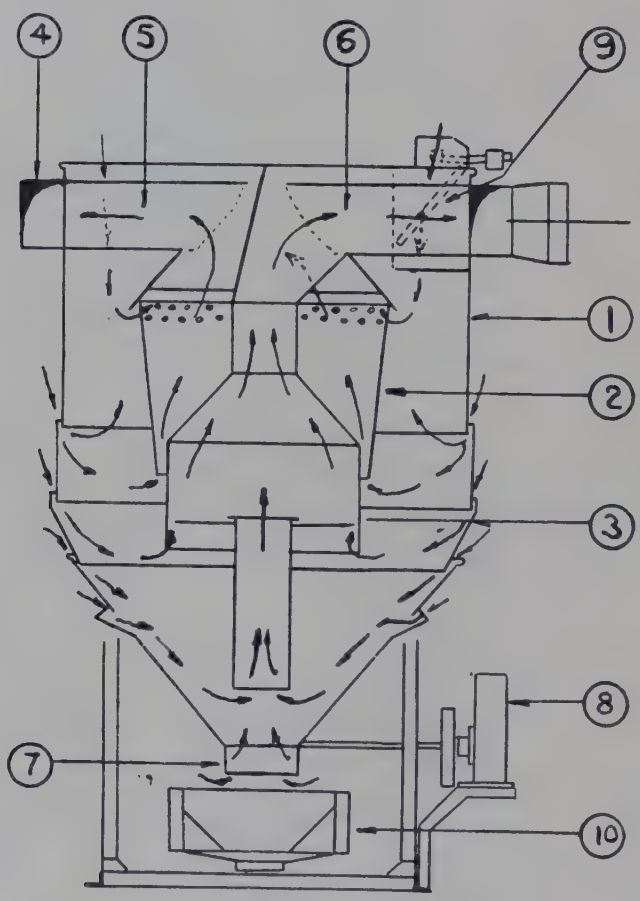


Fig. 92

(1). Cylindrical body of Cooler, (2) Distribution Cone, (3). Internal Exhaust Ducting, (4). External Exhaust Ducting, (5). Duct connecting 2 with 4, (6). Duct connecting 3 with 4, (7). Discharger, (8). Stop and Start device, (9). Flap Valve, (10). Oscillating Screen.

air from different points down the length of the cooler. A feature of the cooler, for which the makers claim some merit, is the short path of each air stream through the cubes, thus ensuring that only air of minimum temperatures shall be in contact with the cubes.

The air flows are clearly shown by the arrows in the diagram. The flow of the cubes through the cooler is controlled by a stop and start device, actuated by the movement of the flap of a bin level indicating device. The cubes flow over an oscillating screen before being bagged. In this cooler, the air is drawn through the cubes, not blown, and this feature ensures that dust from the cooler shall not be blown all over the working space, but is collected in a cyclone separator.

A second type of cooler is shown in Fig. 93. In this apparatus, the incoming cubes slide down the outside of a perforated cone and then down the inside of an inverted perforated cone. Underneath, and surrounding the inverted cone is an air chamber connected by ducting to a fan. The air which may be blown or sucked passes through the perforated cones and the body of the cubes. The cube flow is controlled by a slide connected to a bin level mechanism and the cubes are screened before bagging.

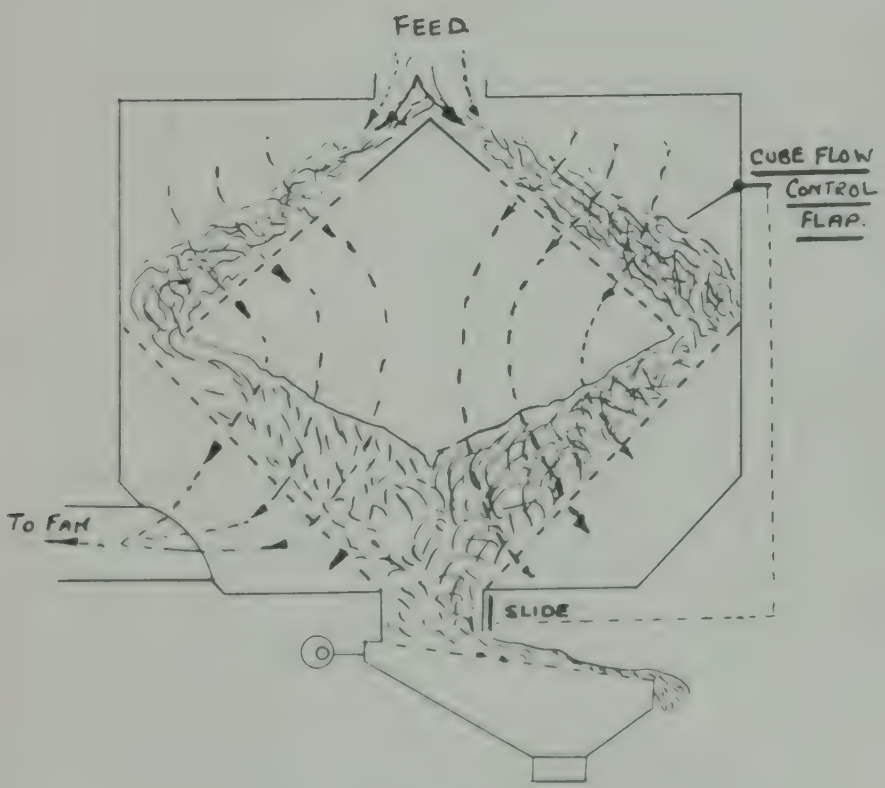


Fig. 93. Gravity Flow Double Cone Cooler

The patent "flare" cooler, shown in Fig. 94, consists of a narrow bin through which the cubes gravitate. The two larger sides of the bin are perforated and louvred to allow the cooling air to flow from the chamber (A), through the cubes, and out by the flared duct (B).

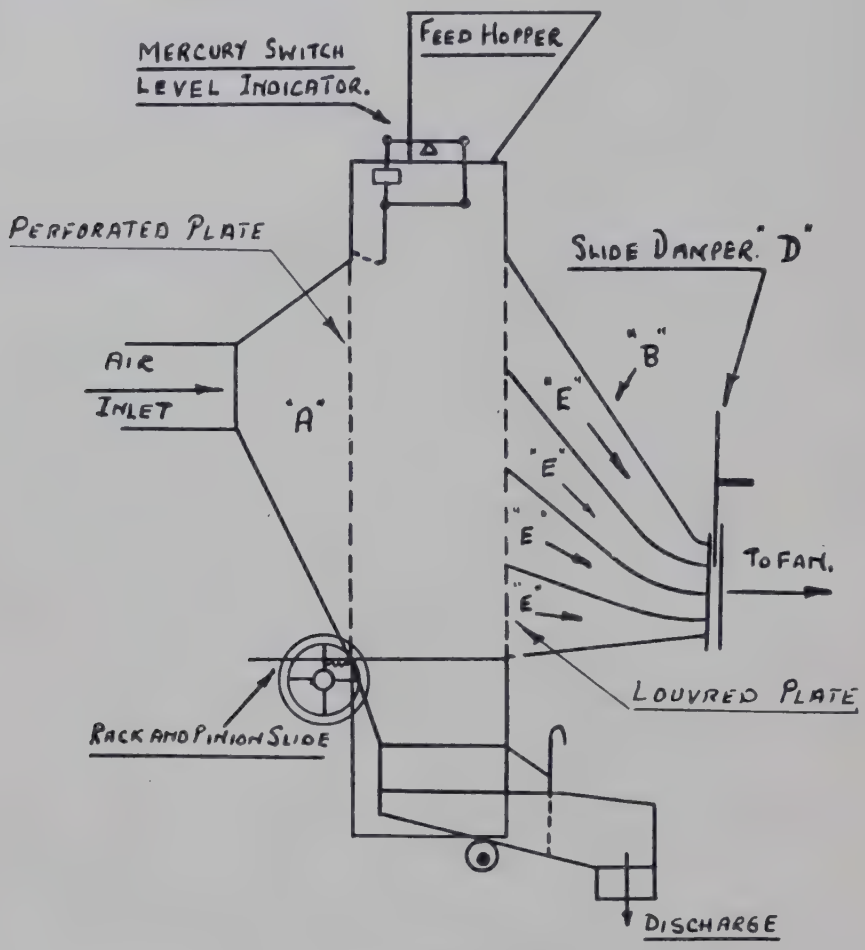


Fig. 94. Flare Cooler

A feature of this cooler is the control of the air flow by a damper (D), which may be positioned to blank off one or more of the air exit ducts (E). This means that the cooler can work satisfactorily, even if the amount of the cubes in the cooler is not sufficient to fill it; as occurs when filling or emptying. When the cooler is full any lowering of the cube level is indicated by a light signal from a bin level indicator.

Of the conveyor type coolers, many examples may be found, but the general principles may be indicated by two types.

The first consists of a woven wire conveyor band running over normal conveyor pulleys, and housed in such a way that air currents can be directed through the cubes several times during their passage along the length of the conveyor.

From the sketch (Fig. 95), it will be seen that the space between the conveying flight and the return flight of the band is formed into air chambers, each having their own air inlet. The space over the cubes, which is closed by the top of the casing, is also divided into compartments by hinged partition plates. The air inlets are connected to a common air trunk which carries the air from a forced draught fan. The air entering each inlet is controlled by a slide; when working, the cubes are conveyed in the direction shown with the hinged flaps resting on their top surface. Air is admitted and takes the tortuous path shown by the arrows to the feed end of the machine where it discharges through the feed opening.

An obvious disadvantage is the lack of control over the exhaust air which may carry a considerable quantity of entrained dust.

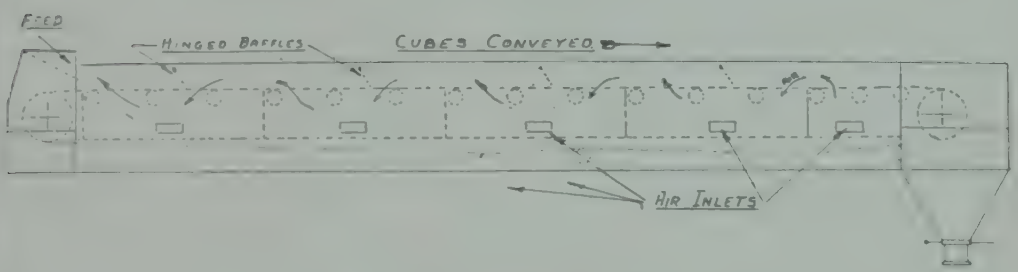


Fig. 95. Conveyor Cooler

A second conveyor cooler is the multi-pass type having conveying bands of cotton canvas or similar material. The cooling air passes over the face of the cubes from one side of the conveyor to the other, but the multi-pass effect allows the cubes to be turned over at the end of each pass. The flow of air is partially controlled by the doors covering the exits louvres in the side of the conveyor (Fig. 96).

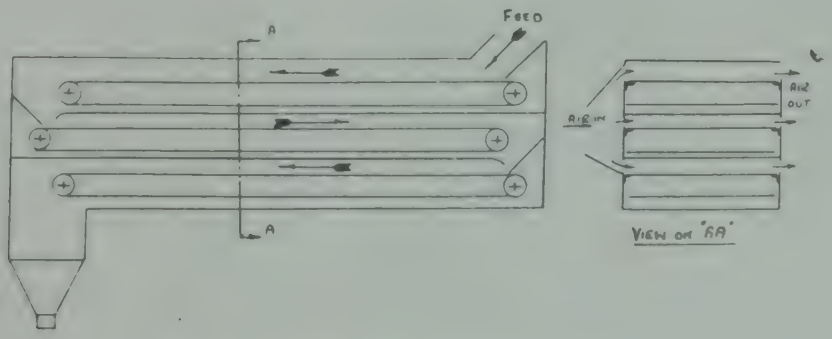


Fig. 96. Multi-Pass Conveyor Cooler

Relationship Between Mixing, Cubing and Cooling Plants

The first tentative effort at flow sheet construction was used to show the run of material through the intake plant. That diagram can now be usefully extended to include the mixing, cubing, and cooling stages. New symbols will be needed, to indicate the machines of these processes, and students should bear in mind the possibility of symbols being used to indicate processes themselves, as a preliminary or alternative to indicating actual machines.

In the diagram shown in Fig. 97, the mixing hopper is of the fixed tipping hopper type, discharging into a batch mixer of the horizontal trough pattern. The mixed meal is discharged into a mixed meal bin from which it is delivered by a shoe feeder into a kettle.

The meal, having been mixed with molasses by the action of the stirrers in the kettle, is now fed in a continuous stream into the cubing machine which is of the gear wheel type. From the cubing machine, the cubes are cooled in a gravity flow cooler.

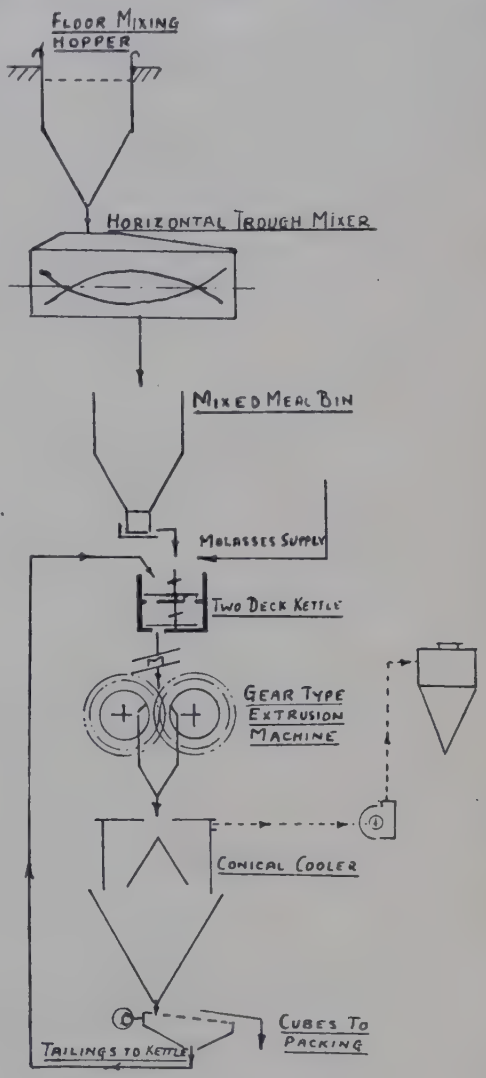


Fig. 97

It should be noted that the meal and broken cubes, known as tail ends or tailings which are separated by the oscillating screen, are returned to the kettle for re-processing.

Packing and Weighing of Cubes

Cubes are commonly packed into 140 lb. bags, either through a simple sacking off spout or through semi-automatic, or a fully automatic weigher. Bags filled through a simple bag spout are weighed on a portable platform scale located near the sacking off point. A multiple bag table may be used where there is a high rate of flow from the plant.

The bag table illustrated in Fig. 98 consists of a circular plate having several bag spouts fitted to it. This plate is revolved round the floor stand and thus each bag in turn comes under the delivery or filling point. As each full bag is moved away from the filling point, it is taken off and replaced by an empty bag. Near to the scale is kept a bag, or box, full of the same kind of cubes as those being sacked off, and cubes are taken from this stock, and put into the bag being weighed or vice versa, as the weighed bag is light or heavy. A numbered complaint slip is then put into the weighted bag, after which it will be sewn up and sent to the warehouse to await despatch.

The method of packing and weighing outlined involves a lot of handling, some of which could be avoided by the use of automatic weighers in the sacking off spout. Several types of weighers are available for this class of work, and mention may be made of the Simon "Reform" weigher, the Avery electrically operated weigher, and the Richard Simon combined weigher and check scale.

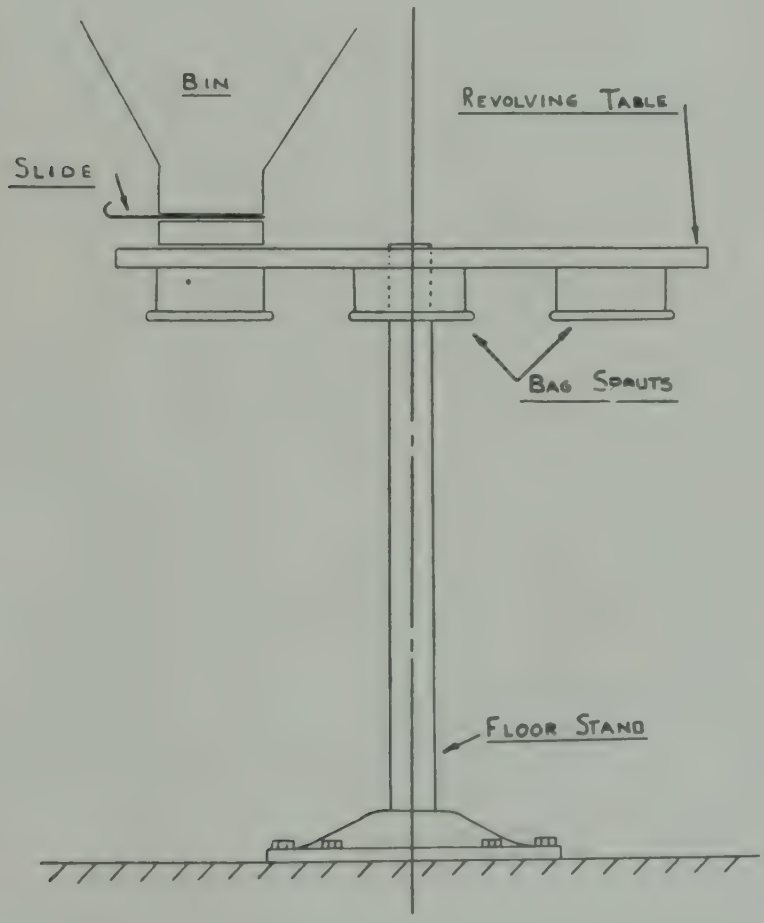


Fig. 98. Bag Table

One of the difficulties encountered in the weighing of finished products is the satisfactory feeding of the weigher. In the "Reform" weigher, this is overcome by using a short band conveyor whose drive is interrupted by the sinking of the weigh pan under load. The "Reform" weigher has the normal type of steel weigh bucket for holding the material to be weighed, and each completed weighment is discharged into a hopper below, to whose outlet is fitted the bag to be filled. Both the Avery weigher and the Richard Simon weighers use the bag as the weigh pan. Packing weighers may be fully automatic, discharging each weighment as it is completed, or the weighment may be held until the attendant releases it, or again, the last dribble feed to complete the weighment may be operated manually. Whichever weigher is used, once the filled bag has been taken off the machine, it can be transferred to the warehouse without the necessity of interrupting the journey as is necessary with the platform scale method of weighing.

The closing of the full bags may be done on a bag closing machine or as is more common, it may be stitched by hand either at the sacking off point or in the warehouse.

This concludes the outline description of the manufacture of cubes, but no mention has yet been made of the various other products of both compound and provender mills. These will include the meal counterparts of the various cube mixings as well as special meals like molassed meal, calf meal and poultry meals and pellets, and from the provender mill, maize grits, flaked maize, barley meal, ground oats, clipped and crushed oats, and several straight meals made from peas, beans, oil cake, etc.

Compound meals generally, have much the same process flow as the cubes, except that in recent years, meals have not been subject to cooking, excepting perhaps molassed meal. The grinding of materials for meals needs to be finer than is necessary for most types of cubes, and more complete dressing of the ground products will be carried out; the separated larger fractions being returned for regrinding. Special feeds, like calf meal, need even finer grinding and closer dressing than the standard dairy meals and fattening meals. Poultry pellets may be made in exactly the same plant as cattle cubes, except that the die plate of the cubing machine will be changed for plates having holes of a size to make the much smaller pellets, and it will, of course, be necessary to change the sizes of the screens between the cubing machines and the cooler. The output of an average cubing machine will be reduced by about half when making pellets.

Molassed meal, consisting as it does of 50 per cent. molasses, needs to have a good absorbing meal for a base, and extracted palm kernel meal is commonly used for this purpose. It is of

great assistance to keep both the meal and the molasses really warm, for this reduces the viscosity of the molasses, and if the cooking is done by "live" rather than jacket steam, a further quickening of the absorption process can be anticipated.

It will be noted that no dry meal mixing is required for the manufacture of molassed meal, and this means a considerable simplification of the plant required. The actual mixing of the meal and molasses may be done in any of the machines previously referred to as being suitable for molasses handling. The jacketted kettle with stirrers is popular; the horizontal trough mixer is used quite widely, and the latest "Cascade" mixer, with steam atomized injection of molasses, is steadily increasing its adherents.

The cooling of cooked meals always bristles with snags, the chief one being the difficulty of using a high speed current of cooling air without carrying the meal away with it, except, of course, where a cooling conveyor of the pneumatic conveyor type is used. A convenient cooler for molassed meals is the scraper conveyor type in which the meal is dragged along one or more flights of steel sheet by bars attached to endless chains.

A fair amount of cooling can be achieved by dropping the meal down a long, large cross section vertical chute, with a bagging off hopper at the bottom, and also various types of cascade coolers are used for meal cooling in almost all cases without the aid of mechanical draught.

CHAPTER X.

FLAKING PLANT

The flaking process consists of cooking the cereal and passing the cooked grains between a pair of smooth rolls. Increasing the moisture content of the grain is nearly always a necessary preliminary, except perhaps with such home-grown cereals whose moisture content is already sufficiently high. The preliminary process is known as conditioning, and is carried out by adding measured quantities of water to the cereal, which is then allowed to remain in a conditioning bin until the moisture has been absorbed and become evenly distributed throughout the body of the seed. The cooking is done by "live," or "open" steam, which further increases the moisture content of the seed, and renders it warm and moist for feeding to the flaking rolls. The seed, now rolled into flakes, is then dried and cooked before packing into bags.

A typical flaking plant flow sheet is shown in Fig. 99. The water wheel damper is illustrated in Fig. 100. The disc (A) carrying the buckets (B) is driven from the paddle bladed rotor

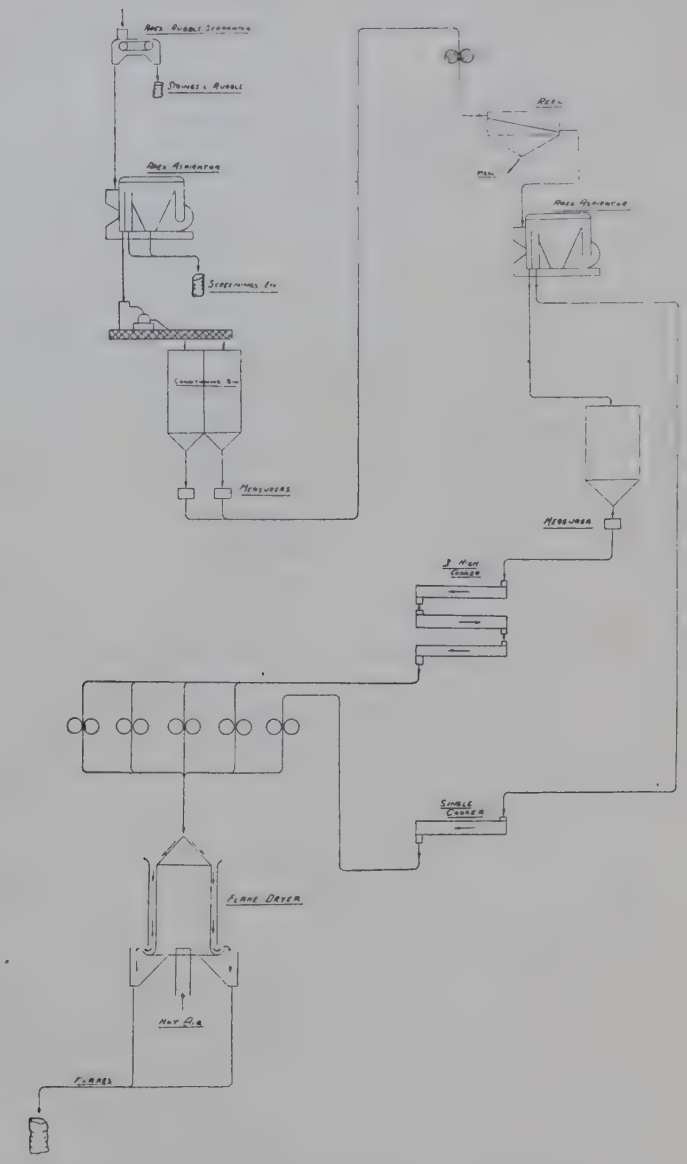


Fig. 99. Flaking Plant Flow Sheet

housed in (C). The lower segment of the bucket disc is submerged in water contained in tank (D). As the disc revolves, the buckets fastened to it are filled with water which is discharged on to the trough (E), from whence it runs via a pipe on to the material being conveyed along the worm trough (F). The rotor which drives the bucket disc receives its movement from the flow of grain passing through the chamber (C), and it will be clear from this that the amount of water added will depend upon the flow of grain through the chamber. A further refinement is the mounting of the buckets on pivots, which allows any number of buckets to be reversed, in which position they will not carry water to the trough (E).

The reducing roller mill was referred to in a previous chapter. The worm cookers shown are cylindrical troughs fitted

with jets through which steam is played on the material being conveyed through the troughs by a paddle bladed worm. The cooked material should then be fed directly to the flaking rolls with the minimum of intermediate handling.

The flaking rolls consist of a pair of smooth rolls which are usually about 18 inches diameter and 30 inches long, although other lengths are obtainable. The rolls are mounted in cast-iron side frames, and one roll is adjustable to enable the clearance between the rolls to be varied to suit the process requirements. Both rolls revolve at the same speed and may be independently driven. Running against the underside of the rolls are scraper plates which keep the rolls clean.

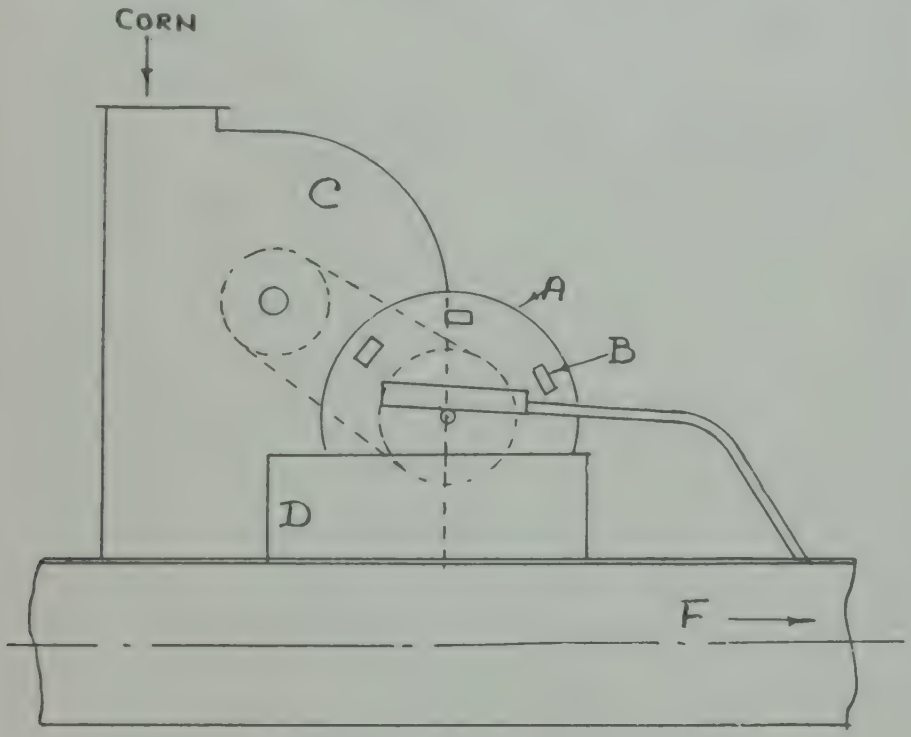


Fig. 100. Water Wheel Damper

The aspirator which is used in the maize flaking plant consists of a chamber fitted with partitions as illustrated in Fig. 101. The split maize from the fluted rolls is fed into the aspirator, and a fan draws a current of air through the feed to carry away the germ and light particles. The speed of the air current is controlled so that it will just carry the maize germ into the second compartment, and the lighter particles and dust into the third compartment. The maize germ is cooked and rolled separately from the heavier corn, and the germ flakes are reintroduced into the main flake stream just before the dryer is reached.

The dryer shown in the flow diagram is of the vertical type, and consists of two cylinders of perforated metal so mounted as to leave a vertical annular space between them. The flakes

enter the top of the annular space and at the bottom come to rest on a horizontal circular plate. The outer cylinder can be lifted up and down, and its position controls the discharge of flakes from the drier. The discharged flakes tumble into a circular trough from which they are swept by revolving brushes.

Air which has been heated by passing over a nest of steam tubes, is blown up the inside of the inner cylinder, passes out through the perforations, through the wall of flakes moving down the annular space, and escapes through the perforations in the outer cylinder.

In the bagging of flakes, it is desirable that they should be firmly packed, and to achieve this, the bags may be mechanically possed.

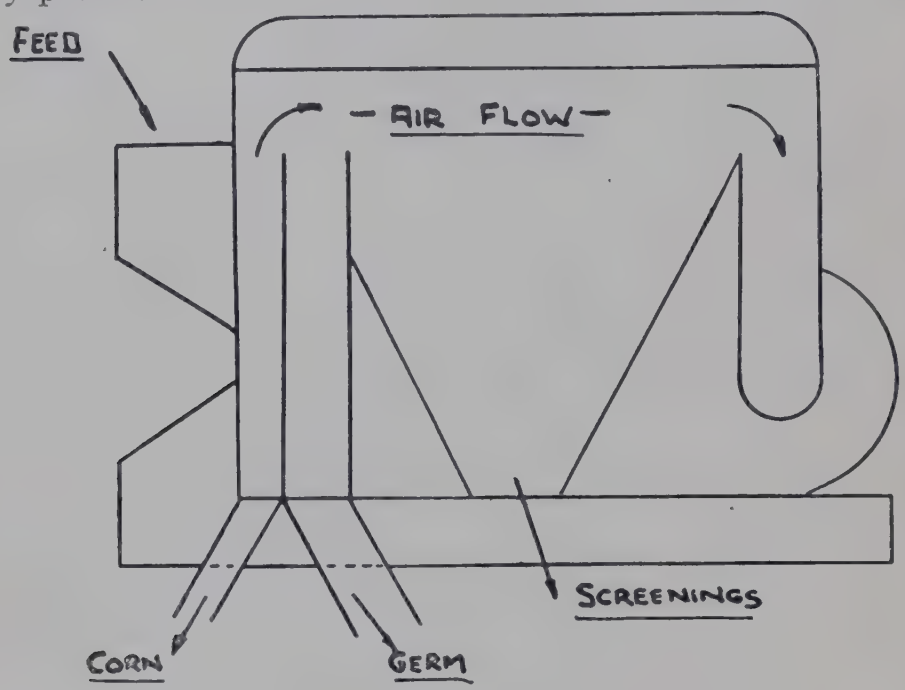


Fig. 101. Aspirator

CHAPTER XI.

LOADING OUT

For the purpose of despatching manufactured products from the mill warehouse, the most common device is a chute leading from the storage floor to the platform of the waiting vehicle. The most common form of chute is the spiral, which may be either single or double. The spiral chute consists of a "U" shaped trough wrapped round a centre vertical column in a manner similar to that of the blade of a worm conveyor.

The delivery end of the spiral terminates in a straight retarding length of chute which forms a table for the carter to pick the bag from. The position of the table above the cart

level may be at shoulder height or chest height, depending upon the practice of the particular mill. The loading out table may be permanently fixed to the external wall of the building or may be hinged to a floor stand located in a covered loading bay.

By the incorporation of hinged sections, the spiral chute can be arranged for use as a floor to floor chute, and whilst this feature is not of use in loading out, it should be borne in mind, for this obviously increases the versatility of the appliance.

An alternative to the spiral chute is the Swift Sure chute, consisting of a vertical drop with a specially designed curve to the horizontal at the bottom which reduces the velocity of the bag without shock.

For discharging sacks from a first floor level, a simple, straight chute is quite satisfactory, but for higher floors, the loss of floor space occasioned by straight chutes and the difficulty of controlling sack speed prohibits their use. Friction hoists which have already been described with the intake machinery, are also considerably used for loading out, but chutes, and particularly spiral chutes, are much more effective.

For sites where only a very shallow angle of chute is possible, use may be made of the gravity roller principle. In this chute, the bottom is composed of a number of closely pitched small diameter rollers, upon which the bag is conveyed without having to overcome any sliding friction.

For loading sacks from warehouse ground floor levels, a number of designs of portable bag loaders are available which have already been discussed under stackers, although it is common to find the mill lower floor located at cart platform level.

CHAPTER XII.

DUST EXHAUST

The dust laden air from plant exhaust installations, pneumatic conveying installations, and pressure reliefs from grinding plant must be stripped of as much dust as possible before discharging it to atmosphere. This problem should be differentiated from the separation of material from the carrying air in pneumatic conveyors for which purpose a simple expansion chamber and/or cyclone separator are quite adequate. For the finer dusts, however, fabric filters are almost essential, although use may be made of large expansion rooms.

The fabric filter may be composed of a nest of hanging sleeves fastened at the top to an expansion box, and each sleeve being closed at the bottom by a tie. The surface area of sleeves will be determined by the volume of air to be filtered, and any tendency to skimp this will result in an undesirable back pressure on the blowing system.

The dust separated from the air accumulates in the bottom of the sleeves and this, plus the dust which adheres all over the inside face of the tubes, emphasizes the need for plenty of clean filter surface to begin with. The accumulated dust in the bottom of the sleeves is emptied periodically by undoing the tie of the sleeve. The dust adhering to the walls of the sleeve is dislodged by shaking.

More elaborate filters have boxes at both top and bottom of the sleeves, the bottom box serving as a receptacle for the separated dust. The bottom box will need emptying from time to time, and if the available space will allow, the box should have a hoppered outlet to facilitate this. A flat bottomed dust box will need scraping out through doors provided in the sides.

Again, more elaborate filters have a mechanism for shaking the dust from the tubes automatically and continuously, and a discharge worm or scraper continually removing the deposited dust through a suitable air lock.

Dust Room

An alternative to the fabric filter is the large expansion chamber provided by a dust room. The size of the dust room will vary with the volume of air to be handled and the reduction in velocity required to effect a separation of the entrained dust. The room, which may be divided into several decks, is ventilated to the atmosphere outside the mill, usually through the roof. The floors formed by the decking are traversed by scraper conveyors which discharge the deposited dust into worms delivering from the room through suitable air locks.

The adequate exhausting of plant and ventilation of working spaces are most important features of compound and provender mills, both from the point of view of health and the reduction of fire and explosion risks, and also from the point of view of efficient working. Dust allowed to accumulate will quickly pile, and soon the mill presents the appearance of a miniature Sahara which, like the Sahara, inhibits activity.

Factory Act legislation requires the miller to maintain certain standards of cleanliness and to adopt certain preventative measures for the limitation of explosion risks. This subject, however, belongs to a later syllabus and is only noted here to give point to the use of dust control apparatus.

CHAPTER XIII.

STANDARDS OF QUALITY

This is a subject which does not lend itself so readily to brief reference as do many of the previous subjects. To avoid giving a misleading picture, it is almost essential to explore fully that

characteristic of the mill's productions which sets the stamp on the miller's exertions. The proof of the produce is literally in the eating, and the highest economy in production will avail nothing if the highest quality is not a permanent characteristic of the mill's output. "Permanent" is a most appropriate term to use in this connexion, for nothing is more damaging to a miller's reputation than fluctuating quality of products.

Keeping the introductory warning in mind, students may consider the following points:

Firstly, certain minimum standards of purity are required by law and the student is advised to procure for himself a copy of the "Fertilizers and Feeding Stuffs Act, 1926." Certain minimum variations in feeding values are required by the Act, and whilst this is largely governed by the ingredients composing the food, bad mixing and careless processing can nullify the best of mixing formulæ.

Homogenity or consistency of content is then an important standard of quality. That there shall be no poisonous or deleterious substances present is self-evident, but it should be borne in mind that pieces of wire, stone, glass and the like can be just as fatal to livestock as the chemical poison of castorseed. The elimination of castorseed is largely the business of the chemist, but the tramp iron, stones, etc., are subject to the care of the cleaning machinery and the men who attend them.

The best of materials can be spoilt by poor working. Feeding stuffs packed in too hot or moist condition in the mill present the farmer with an uninviting, if not actually harmful, feed for his animals.

CHAPTER XIV.

SUMMARY OF GENERAL PRINCIPLES

Substantially the whole of the City and Guilds intermediate syllabus has been referred to so far in Part II, even if only in a brief manner. The purpose has been to give newcomers to the industry some conception of the nature of the industry, of the variety of the materials which are handled, and of the kind of work which is done on them.

The first distinctive feature of the industry to be noted was the extraordinary range of raw materials from which the miller makes his products. Few industries, if any, within the confines of a single mill handle such a wide range of materials having so many different characteristics.

It should be noted, too, that many of these raw materials as received by the compound miller are the waste products of other industries and of no direct use to man except perhaps as fuel.

By the alchemy of the miller, the farmer, and his livestock, these wastes are transformed into such valuable commodities as milk, bacon, eggs, wool, meat and leather, and note also that many of the industries whose by-products are thus so profitably disposed of would be seriously embarrassed were this outlet for their wastes not there.

It is desirable that the relationship between the miller, the farmer and his livestock should always be kept in mind. To be engaged in the manufacture of feeding stuffs as an end in itself is not nearly so satisfying as being concerned in the production of valuable commodities like milk, wool, meat, etc. To this end the industry may profitably be thought of in terms of the ultimate yield from its products.

This diversity of raw materials complicates the handling and storage problems, particularly in a mill which is highly mechanized and where materials are handled in bulk.

A second feature of the feeding stuffs industry to which attention has previously been drawn is the range of machines which have been designed to do the same job, and it was suggested that this, to a large extent, is due to the empirical basis of their design, in the absence of precise knowledge of the fundamental laws governing the work the machines are required to do.

A considerable number of the machines have been described and they were linked together to form complete plant units. The relationship between the machines was illustrated by the construction of simple flow sheets of the mill processes.

It was found that some of the machines were peculiar to particular mills. Many examples of self-designed machines are to be found in the industry. Sometimes these machines are jealously guarded secrets, in which case they are known only to those who design and operate them. Many such machines are protected by patent regulations and here knowledge of them is available even if their use is confined to the patentee.

Specialist machines of this category will tend to diminish in number as engineering firms devote more attention to the compound and provender milling industry. It must be remembered, however, that the empirical basis of design is so much in evidence that without having full access to a mill as an experimental station, the machinery manufacturer is labouring under a severe handicap.

Sometimes, in return for facilities in his mill, a miller will receive from the machinery manufacturer special concessions in the use of the machinery concerned. Large milling concerns may develop their maintenance department to a point where the engineers become machinery manufacturers, constructing machines solely for use in that mill.

All these features contribute to the heterogenity of com-

pound and provender milling machinery, but in spite of this, there is a large number of machines which are common to practically all mills and what is of more concern to the student, although machines vary, the principles of the work being done by mill and mill display substantial unanimity. Students should, therefore, be more concerned with the thorough understanding of general principles rather than with the cataloguing of all the multifarious machines which are or have been used in their industry.

The range of the industry's raw materials is almost equalled by the range of finished products which in normal times leave its mills. One of the effects of this range and diversity of materials and products is the need for maintaining the maximum flexibility of plant and process flows.

Flexibility in this connexion means the ability of a plant unit to handle a range of different products by minor variations of flows and easily made adjustments to the machines comprising the unit. A point is reached, however, where the increased complication of the plant needed to achieve extra flexibility is not justified by the value of the extra flexibility obtained. For example, meal units may handle a whole range of fattening and dairy meals, but a product like calf meal may have a plant unit all to itself. On the other hand, a single unit may be used for meals, cubes and pellets by simple adjustments to machines and use of alternative chutes.

Some of the factors which decide whether or not a product shall have a unit to itself are :

(1) The average demand for the product.
(2) The degree by which the ingredients of the product may vary from those of other products.
(3) The difference in the actual processing required by the product, from the processing required by the bulk of other products.

Consideration has been given to a number of machines and devices for the removal of foreign bodies from the raw materials. The existence of these machines suggests that the cleaning process is a very necessary one. Apart from maintaining the purity of the finished products, always the most important consideration, the removal of foreign bodies is essential to the smooth running of the plant and machinery. Even the presence of an apparently innocuous material like string, if allowed to persist, can stop a whole plant by blocking conveyors, chutes and machines. Neglect in this matter may result in the shaft of a worm conveyor, particularly the paddle bladed type, being built up until the effective volume of the worm trough is reduced to practically nothing. Tramp iron is an obvious destructive agent; string an insidious one, whose continual

nibbling at production capacity, if neglected, will be reflected in increased working costs.

After the removal of foreign bodies, it is sometimes desirable for some processes to remove from a raw material substances which are naturally associated with it, like chaff and straw, and this may be done by the use of mechanical screens and aspirating devices. The need for working only cleaned materials is common to all mills and will be neglected only to the miller's cost.

Size Reduction

Size reduction machines were found to be an essential feature of the mill, and here again, the principle of reducing raw materials to a comparatively uniform particle size is common to all compounding processes, irrespective of the kind of machines favoured by different millers. Indeed, it would be true to say that the blending of balanced rations would be impossible were it not for the size reduction principle. In considering size reduction, however, sight should not be lost of the fact that some size reduction machinery may be used for the purpose of separating the component parts of a seed, or the making more readily available the nutriment contained by the material being treated. For example, linseed (the original seed, not the oilcake) which is sometimes fed to sick animals and calves, if given whole, would pass through the intestines undigested; it is necessary, therefore, to crush or cook the seed before its properties can be utilized by the animal.

The Importance of Mixing

Mixing is the heart of the compounding process. All the miller's efforts depend upon the sufficiency of his mixing for their proper reward. The conditions affecting the mixing process have been referred to, and those conditions apply to all mills. The majority of mixing is of dry materials, followed by the introduction of small quantities of liquids like molasses or cod liver oil. The introduction of liquids is, however, more of an adsorption process than a mixing process, especially in the case of molassed meals containing up to 50 per cent. of molasses. It is, of course, still necessary that the liquid be distributed or adsorbed equally throughout the body of the meal.

Cooking and Cooling

The practice of cooking the products in the course of manufacture varies considerably from mill to mill. Some mills do so little as to hardly justify the use of the term cooking, whilst others raise the temperature of the products with open and closed steam to near the boiling point of water; other mills practice a more moderate cooking. The principle of cooking is perhaps subject to more variation than any other principle of compound manufacture.

Some manufacturers assert that even moderate heating of the product destroys some valuable feeding properties; others consider adequate cooking necessary to the conditioning of the foods and to the compressing into cubes. Some materials, like linseed need to be maintained at a high temperature for sufficient time to destroy the enzymes which might otherwise generate toxic substances when the material reaches the stomachs of the livestock to whom it is fed.

Next we come to cubing, and here we return to a principle which is widespread throughout the industry. Particle size, moisture content, oil content, mixing, cooking, all have an effect upon the compression of meals into cubes. Nor must the effect of a binding agent like molasses be omitted. That the first cube of a batch shall have the same content as the last cube of the batch will be agreed, and the merit of cubes as a feed will be readily admitted when it is considered that, in eating that food in the cube which it finds palatable, the animal or bird is obliged to eat that which it does not find so palatable but which is nevertheless of benefit to it. Cubes that fall to pieces upon the slightest provocation are obviously unsatisfactory, and care must be taken to avoid this undesirable characteristic.

Many compound feeding stuffs are sold in meal form and a good standard of homogenity should persist throughout the mill's whole output of any particular class of meal. Special purpose foods, like calf meal and cream substitute, have their own particular standards, such as particle size and the ability to form good gruels, and attention will have to be paid to the achievement and maintenance of such characteristics.

Cooling is closely allied with cooking in that the need for one is dependent upon the use of the other. The principle of packing materials in bags only at suitable temperatures is common to all mills whether cooling is, or is not, required to obtain that temperature. Where cooling is necessary, then there are principles of cooling which need studying. Coolers may vary, but the principles hold good universally and machines may be valued by the extent to which they follow the principles.

A number of other process principles could be named, such as flaking, washing, polishing, drying, conditioning, which are distinct from the machines which are used to carry out the processes and unlike the machines, the process principles are applicable to all mills.

Having made the acquaintance of the appearance of compound and provender milling plant, the primary object of students should now be the mastery of the universal principles. That mastery will not be won easily, for there is yet a lot to be learned even by the experts. Evidence will arise which will appear contradictory, but by continual testing of all theory by practice, a substantial body of knowledge will eventually materialize.

Concurrently with the study of principles will run the examination of the machines in which those principles find their practical expression.

This states the common ground upon which all students of the industry can meet.

CHAPTER XV.

FLOW SHEETS

The subject of flow sheet construction has already been referred to, but it is felt desirable to stress certain conditions which should be observed in representation of even the simplest flow.

A flow sheet must convey its information clearly and accurately, and this becomes difficult, if not impossible, if the layout is cramped. The direction of flow must always be indicated by suitably placed arrow heads. When a flow is shown coming from a machine with no indication of its destination, as, for instance, might occur with sand from a screen, it is a mistake to put the arrowhead pointing to the part of the machine from which the sand is proceeding. The correct method is, of course, to have the arrow indicating a movement of the sand away from the machine, as in Fig. 102.

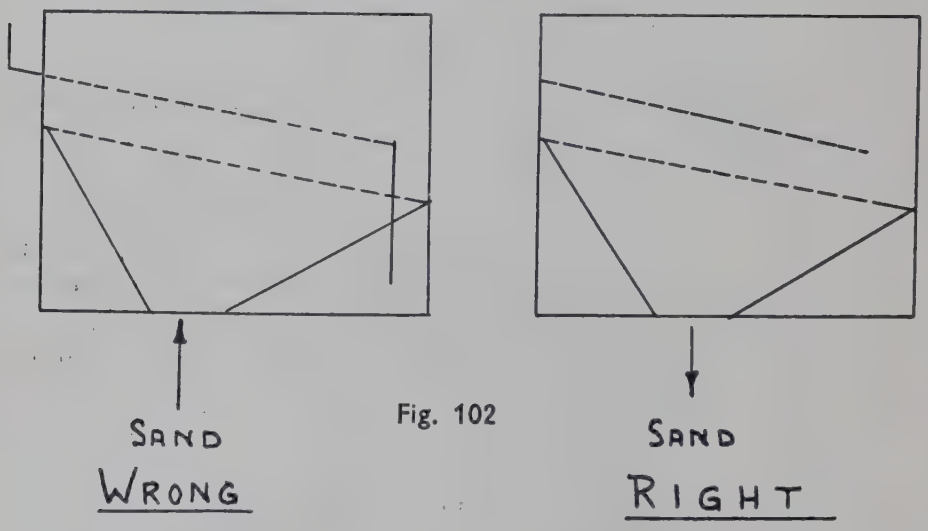


Fig. 102

The relative positions of the symbols bears no fixed relation to the relative positions of the machines they represent. If it is necessary to show the relative positions of the machines in the mill, then a layout or installation diagram or drawing is necessary. For flow sheet work, however, the symbols are located in such positions as will tend to implement the purpose of the flow sheet, which is to give clear and accurate information about a process flow. If, as may very easily occur, the placing of the

symbols in the relative positions of the machines, lends itself conveniently to the flow lines, so much the better, but the essential thing is the flow line and not the machine position.

The placing of symbols to suit flow lines means that elevating and conveying machinery are almost never indicated in flow diagrams, the exceptions being where the flow sheet is drawn to show the path of the material through a handling plant and/or store, and where a special use of handling equipment has to be indicated. The movement of material from one plant item to another is completely indicated by the flow line connecting the two items, the direction of the flow being shown by arrowheads placed on the line.

The symbols should be as much like the machine they represent as is consistent with ease of drawing, and flow lines into and out of the machines should be located as far as possible similarly to the actual inlets and outlets. The only variation from this principle occurs where symbols do not represent actual machines, but the work the machine does.

Flow sheets in which the symbols represent process operations may be used to state the general principles of a process, whilst the application of the principles to actual plants is shown by the more usual flow sheet in which the symbols represent specific machines.

Flow sheets representing process operations may be simple block diagrams, and the use of such diagrams is a helpful preliminary to the preparation of comprehensive flow sheets. The development of a complete flow sheet from a simple block diagram might take the following trend : Assume that it is intended to complete a flow sheet of cube manufacture from the mixing of the ingredients to the weighing of the finished cubes. The first block diagram is shown in Fig. 103.

It will be noted from Fig. 103 that as the block symbols represent processes, each symbol may involve the use or representations of more than one item of plant. The next stage is to draw a second block diagram breaking down those symbols which represent processes requiring more than one plant item for their execution into a group of symbols, each representing an operation which involves only one plant item (Fig. 104).

It now becomes necessary to choose the type of machines which it is intended to use in the plant, and if some uncertainty exists about some of the machines, a further diagram might consist of a number of symbols representing the chosen plant items, together with one or two block symbols representing those operations for which machines had not been chosen. When all the machines, etc., have been decided upon, the flow sheet might appear as Fig. 105.

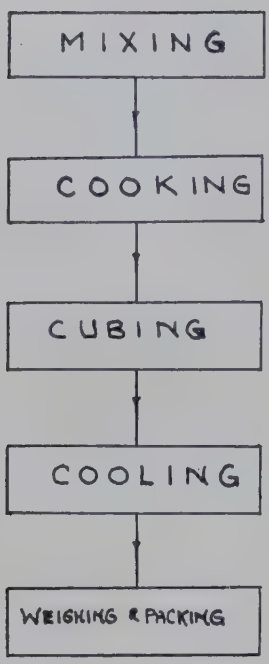


Fig. 103.

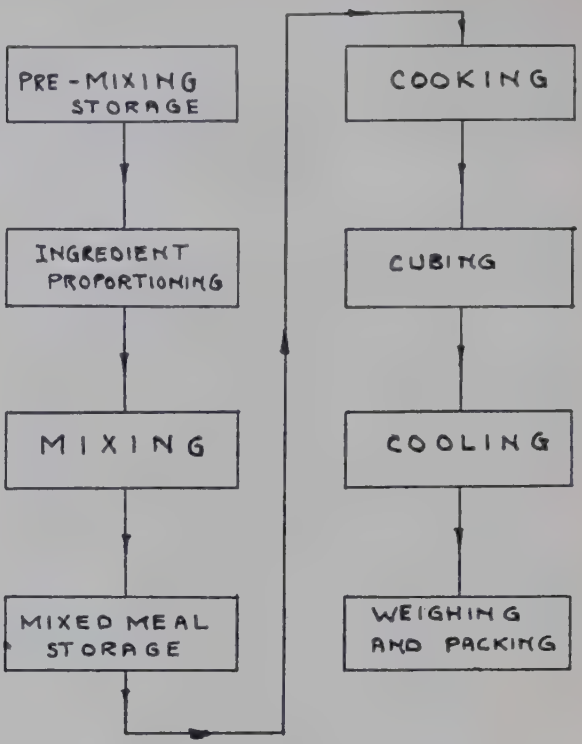


Fig. 104.

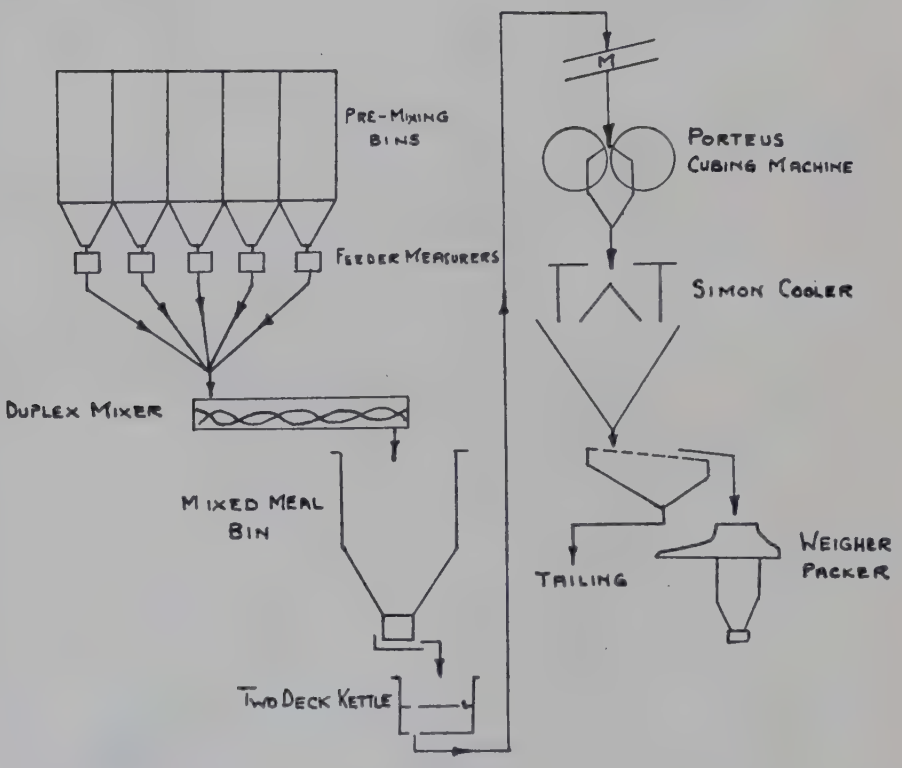


Fig. 105.

To the flow sheet as shown in Fig. 105 would then be added, alongside the appropriate plant items, the size of the item used. Size in this respect does not, of course, imply the space occupied, but the capacity of a bin or a machine as the case may be. It

will be noted, too, that in the transition from block diagram to full flow sheet, certain equipment for the protection of the plant are introduced, in this case a magnetic separator is shown. Other information may be added, such as the size of screens used, but care must be taken not to confuse the diagram by packing it with detail not really necessary to the picture of the process flow.

From the examination of various flow sheets, students will note that some draughtsmen do not put the arrowheads in the middle of a flow line but at the terminal end or at each bend. It should be remembered, that over-simplification of symbols does not necessarily mean increased clarity of a flow diagram.

This development of a flow sheet from a preliminary block diagram tends to ensure the student against the omission of an operational stage from the final flow sheet, and enables him to estimate the kind of layout which will best suit the flow he is to represent. This should avoid the time wasted in making careful symbol drawings of machines only to discover that the layout of the symbols does not allow the flow to be shown to the best advantage.

Value of Flow Diagrams

Careless flow sheet construction may, perhaps, be attributed to some extent to lack of appreciation of the value of flow diagrams to people other than milling engineers. It is true that milling engineers find particular advantage in the use of flow diagrams, but many advantages that are available to the miller by the use of the flow diagrams should not be lost sight of by students.

First of all, it should be recognized that many problems lend themselves to graphical representation, and the consideration of these problems is made easier by the use of sketches or diagrams. The drawing of a sketch relieves the mind of the necessity of maintaining a mental image and leaves it free to concentrate upon the problems involving the image. If, for instance, improvements are required in a mill process, the use of a flow sheet makes it unnecessary for the mind to visualize the layout of the process at the same time that it is attempting to formulate the desired improvements.

The production possibilities of a large mill are easier to assess by the use of flow sheets, and in the case of a compound mill the production possibilities are not nearly so obvious as might be thought. In manufacturing many different products from a wide range of raw materials, the use of plant lends itself to many variations. A flow sheet records and crystallizes these variations in a way no other device can. As a means of communicating information about a process, the flow sheet is unexcelled.

CHAPTER XVI.

RAW MATERIALS

Many of the raw materials are industrial by-products and are largely free from harvest restrictions. Even oilseed residues, which are important enough to be classified by themselves are, in fact, industrial by-products, and their supply, with few exceptions, is largely free from harvest restrictions. This does not ignore the fact that the oilseed crusher who buys the seed must take careful account of the availability of crops, but many oil mills hold such stocks as to enable them to crush the same kind of seed all the year round. In this respect the industries which process the original seeds act as balance bins for the compound miller, delivering to him a steady supply of by-products throughout the twelve months of the year. There are undoubtedly periodic shortages of certain by-products, but in many cases these shortages are economic in origin.

The supply of many materials is, of course, affected by their harvest times, that is, those materials which are received in their original condition, and in this class, we find materials like oats, barley, rye, wheat, maize, locust bean. It is clear from this that, broadly speaking, industrial by-products are available all the year round, whilst the supply of original materials will vary with the harvests. There are, of course, exceptions to this. For instance, beet pulp, which is a by-product of the sugar beet industry, is in greater supply after the harvest of the sugar beet has been processed. Wheat, an original seed, is grown and stored in such quantities as to make it available all the year round. In the case of those original materials which are in supply all the time, the effect of harvest will be noted in a variation in quality and characteristics at different times of the year.

A further factor affecting the supply of original seeds is range of climates in which the seed can be grown commercially, and if this is great, then supply will be maintained subject, of course, to the delay occasioned by transport from the farthest fields. The supply of materials which are imported from other countries will, of course, be affected by the willingness of those countries to export their produce and the ability of the intending importer to offer favourable purchase terms. This again may be conditioned by existing political and economic conditions, and so what seems at first sight a plain straightforward business may, in practice, bristle with complications.

Some few materials are of animal origin and are mainly available all the year round. Fish products may be influenced by the fishing seasons, but if the haul is good, the variation in supply of fish wastes may not be noticeable.

In the preliminary chapters the raw materials were divided into the following categories :

1. Oil cakes.
2. Cereals.
3. Cereal by-products.
4. Leguminous seeds.
5. By-products and miscellaneous.
6. Minerals.

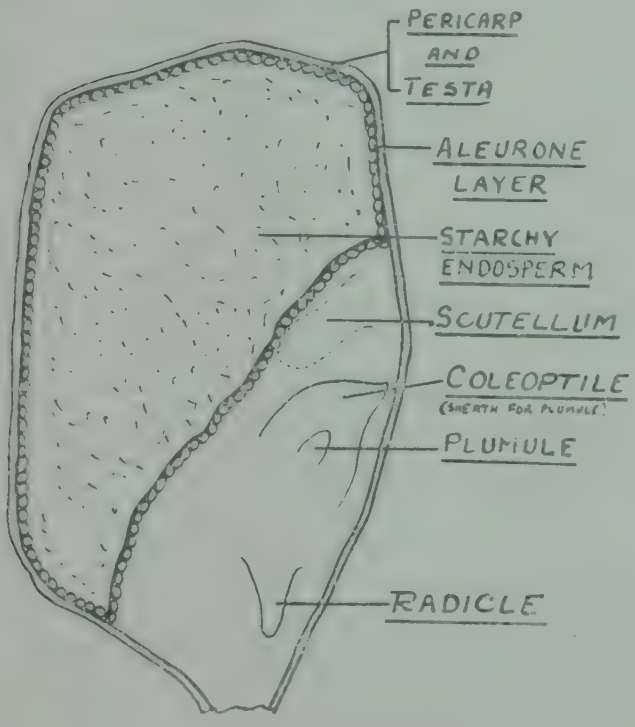


Fig. 106. Maize Grain

From a consideration of the list of materials which are covered by the above classification, it will be seen that all except the materials in category six are of organic origin. Matter generally may be classified as either organic or inorganic. Organic materials are living organisms or the product of living organisms.

Of the organic materials, some few in our list are of animal origin, but by far the great majority are obtained from plant life. Some of the products of the plants are altered by industrial processes before the compound miller receives them, but others are received in the natural state.

The materials which are received in their original condition are the cereals and the legumes, and in studying these materials we are, in fact, studying living organisms. The science of plant life is called botany, and whilst our interest in the seeds is not that of a botanist, we shall unavoidably be confronted by some botanical terms. It is, therefore, desirable to become acquainted with these terms, and whilst it is not intended to consider each separate seed as a botanical specimen, it will be advantageous to consider some of the common features of plant life.

The two most important departments of botanical science are morphology and physiology. Morphology is the name given to the study of the appearance and relative positions of plant organs, and is subdivided into external morphology, anatomy

(which deals with the internal structures) and histology which, roughly, may be said to be concerned with the microscopic structure of tissues and cells. Physiology, on the other hand, concerns itself with investigation into all the processes which make possible the growth of the plant and attempts to answer questions like " How do heat and light affect the growth of the plant?" and, " How does the plant reproduce itself?"

In recent years, the science of ecology has busied itself with the effect of environment upon the form and structure of plants.

The simplest plant life consists of a single cell which carries out all the processes necessary to growth and propagation. In all the highest forms, the plant body is multicellular; that is to say it consists of numbers of cells closely connected together. In multicellular plants, the different jobs necessary to the life of the plant are allocated to different cells.

The living substance of the cell is called protoplasm. In some cells, the protoplasm may be only a thin lining on the inside of the cell wall, and the centre of the cell, known as the vacuole, contains cell sap—a watery solution in which may be dissolved various substances. As plants do not digest solid food, the food necessary to the growth of the cell is absorbed from solutions by diffusion through the cell wall. The dissolved substances are comparatively simple and include mineral as well as organic substances and carbon dioxide. This marks an important distinction between plants and animals. Green plants take in their food material in the form of simple inorganic materials, whilst animals, although they need inorganic salts, must feed on complex organic substances such as fats and oils, carbohydrates and proteins.

In our preliminary considerations, attention has been drawn to the conversion by the miller and the farm animals of waste substances into milk, meat, leather, wool, etc. Here we see another link in the chain, for the living plant changes inorganic substances into the complex organic substances which are essential to the maintenance of animal life.

The building of these complex substances in the presence of light is known as photosynthesis. The organic compounds all contain carbon, and this is obtained by the plant from the carbon dioxide of the atmosphere, obviously involving a breathing process. The fact that plants do breathe is, of course, a very familiar one, but it should be noted that seeds in store also breathe in order to abstract the oxygen from the air to break down the food reserve contained in the seed in order to provide the energy to maintain its life. In the dry seed, the plant is said to be dormant, but this is not strictly true, for in all living cells metabolic processes continue incessantly, even if in the dry seed the process is very slow.

From this point of view then it will be seen that a number

of the raw materials to be studied are not just lumps of dead matter but are, in fact, little bundles of life.

The food substances generally stored in a seed are in insoluble forms such as starch and oil, but sometimes abundant supplies of soluble foods like the various sugars are found. When food substances are insoluble, they must be converted by the plant into soluble substances before they can be directly used, and this conversion is effected by substances known as enzymes.

The whole purpose of a plant in producing a seed is to develop a young plant. To this end, the seed contains an embryo or germ which is always rich in albuminoids, fat phosphates and potash. It also contains a store of concentrated food intended to nourish the young plant.

In the seeds of cereals, the reserve food supply is practically all starch, whilst in the oilseeds there is no starch present (with minor exceptions), the food reserve in this case being fat. In some seeds, the food reserve is chiefly located in the cotyledens. The cotyledens are the rudimentary leaves found in the embyronic stage of the seed germ. In other seeds, the food reserve is mainly outside the embryo in the endosperm.

Some seeds contain one cotyleden and are known as monocotyledens, whilst others contain a pair and are known as dicotyledens. All the true cereals are monocotyledens, whilst buckwheat is a dicotyleden.

The various parts of a seed may be illustrated by considering, say, a grain of maize (Fig. 106).

Maize, like many other seeds of commerce, is actually a fruit or caryopsis. The outer skin of a fruit is called the pericarp. The outer skin of a seed is called the testa. In maize, the pericarp containing the true seed is very thin and is combined with the testa to form a single membrane. This membrane will allow the passage of moisture into the seed.

The seed is divided into two main parts, the germ and the endosperm. In many seeds the endosperm constitutes the food store, and in maize, this is chiefly in the form of starch. Contained in the endosperm and located just inside the testa or seed coat is a layer of protein substance called the aleurone layer. The food reserve of the endosperm is made available to the embryo plant by the action of a structure called the scutellum which, by the secretion of enzymes, converts the insoluble food in the endosperm into the soluble food required by the young plant. The young shoot of the plant, upon germination, develops from the plumule, whilst the roots develop from the radicle.

A simple test for the presence of starch is to cut open the seed and apply a weak solution of iodine to the cut part, when the presence of starch will be indicated by a blue colouration.

It will be understood that the botanist has named far more parts of the seed than have been mentioned in these notes.

CHAPTER XVII.

CHEMICAL COMPOSITION OF RAW MATERIALS

Both the botanical and chemical work introduced at this stage is a necessary foundation to the complete structure of compound milling technology, but may seem more advanced than is required in the first year. It is an unavoidable characteristic of foundations intended to carry large buildings at some future date, that they must be laid comprehensive enough to carry the final structure, although the present intention is merely the erection of a single storey.

Bearing this in mind, consideration may be given to an analytical survey of the nature of our raw materials which are, of course, all foodstuffs. Each raw material may be divided into solids and liquids, for even the dryest of them contains some water. Generally speaking, many of the raw materials

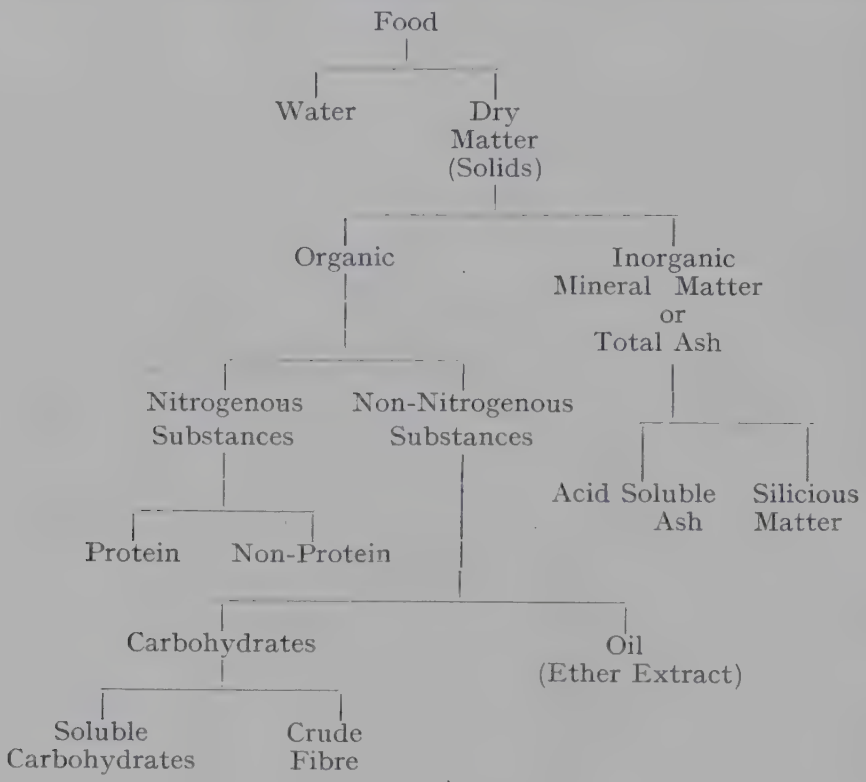


Fig. 107. Composition of Food

received into the mill are de-hydrated (dried) versions of the original substances, as, for instance, brewers' grain, potato chips and beet pulp.

Original foodstuffs are classed as succulent and non-succulent as their moisture content is greater or less than 70 per cent. The dry matter of the material can be divided into organic and

inorganic. In the laboratory, all the organic matter can be burnt off, leaving an inorganic ash of minerals. Some of this mineral ash is soluble in acid, leaving silicious matter or matter which may roughly be described as of a sandy nature. The organic solids may now be divided into those compounds which contain nitrogen and those which do not. It is in the nitrogenous (or nitrogen containing) compounds that we find the protein of the raw material, but there is also present non-protein substance.

The non-nitrogenous substances can be divided into carbohydrates and fats or oils. The fats are often referred to as ether extract, because the chemist extracts them by the use of solvent ether which, however, not only extracts the fats or oils, but also other ether soluble matter like wax and some pigment. For the practical purpose of this study, however, ether extract can be looked upon as oil content. The term oil is used when the ether extract is liquid at normal temperatures and the term fat is used when it is solid at normal temperatures.

Carbohydrates are all composed of the elements carbon, hydrogen and oxygen, but it should be noted that all materials composed of carbon, hydrogen and oxygen are not true carbohydrates, which are sugars or condensation products of sugars. Materials containing a high percentage of carbohydrates are called carbonaceous. Some carbohydrate is not in a soluble form and is classed as crude fibre. Materials containing from 15 to 20 per cent. of fibre may be classed as coarse, whilst to materials containing less fibre than this, the term concentrated is applied.

Fibre is not all indigestible and a proportion of fibre is necessary to good health. The question of nutrition belongs to the final course and the nutritive value of foods will be considered then, but chemical composition belongs to the present course and notes on their composition will be included in the consideration of raw materials which follows.

Oats

There are many varieties of oats, but there is very little difference amongst them as far as composition is concerned. Some varieties of seed oats are sown in autumn and these are known as winter oats, other varieties are sown in spring.

The two varieties of winter oats most commonly grown are grey winter and black winter. The colour, if natural and not produced by weathering, is no real indication of the nutritive value of the seed, there being little difference in this respect between black and white oats.

The husk of oats may be yellow, brown, black or grey in colour. Whatever the colour of the grain, it should be bright and clear. After threshing, the seed is obtained contained in an outer husk, the chaff remaining with the straw of the plant.

In Fig. 108 the chaff is shown under the name of non-

flowering glumes. The grasslike twisted shoot shown growing from the husk is called the awn, but most varieties of cultivated oats are awnless. It will be seen that the chaff normally contains two seeds.

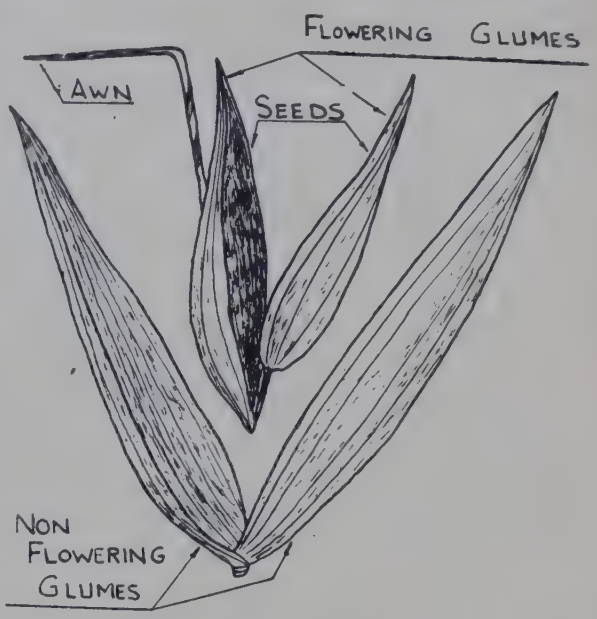


Fig. 108. Oat Spikelet

The oat kernel should be white and firm, with little variation in colour, even though the husk may be white, yellow or black. The proportion of husk to kernel varies and some authorities grade oats according to their husk as follows: 23-25 per cent. fine skinned oats, 26-29 per cent. medium, 30-34 per cent. coarse, 34 per cent. and over, very coarse.

The largest part of the oats received by compound and provender millers is normally imported and can often be distinguished as such by the greater number of weed seeds present. Some of the American oats are very poor and light, whilst those from Turkey and the Argentine are often coarse and dirty. Oats exported from New Zealand, Australia, Canada and Danzig are usually of very good quality.

Darnel and cockle seeds and a specie of vetch if present in considerable quantities usually mark the sample of foreign origin. The quality of cereals is often indicated by their bulk weight, assuming a normal moisture content. This weight is commonly expressed in lb. per bushel and to convert this to lb. per cubic feet it is necessary to multiply by seven-ninths.

The weight of British grown oats varies from 35 lb. to 46 lb. bushel, but good oats should weigh at least 40 lb. per bushel. Foreign samples may be as light as 30 lb. per bushel, but weight should always be considered along with moisture content.

Harvest Times

The home-grown crop is harvested in August and September, the principal foreign harvests being as follows:

	Month of Harvest.	Earliest Arrivals.
Russia	August-October.	November-December.
U.S.A.	August-September.	October-November.
Canada	August-September.	October.

Germany	August-September.	October-December.
Australia	November-December.	January-February.
Argentine	December.	February-March.

Oats are considered as new season oats up to the 31st December of the year of growth in northern latitudes.

COMPOSITION OF OATS :

	English.	American.
Water	13%	7%
Protein	10%	14%
Ether extract	5%	4½%
Soluble carbohydrates	58%	64%
Fibre	10%	11½%
Ash	3%	4%

CLIPPED OATS.

To improve their appearance and to increase the bushel weight, oats sometimes have the ends of their husks clipped off.

CANADIAN FEED OATS.

There are poor quality oats that are often found growing as weeds in wheat crops, principally foreign. They usually contain the screenings of broken seed and weed seed from the wheat.

KILN DRIED OATS.

Oats containing a high percentage of moisture are often dried to improve keeping qualities. Damaged and musty oats are sometimes similarly treated which process does not, of course, redeem the quality of the oats.

The by-products of oats are not likely to be met with in any quantity but may consist of : Screenings, broken grain, weed seeds and particles of chaff ; oat husks, screen dust and oat dust, products resulting from the polishing of the kernel.

Wheat

Very little need be said about wheat, there being a wealth of information available in flour milling literature, apart from the fact that the seed plays a comparatively unimportant role in compound milling, although it is a popular ingredient in many poultry mixings.

Upon being threshed, the wheat kernel is separated from the husk, a feature which marks a difference from oats and barley. The kernel is described as ovoid in shape with a well-marked groove running longitudinally. The position of the germ is marked by a depression on the convex side of the grain at the opposite end to the so-called "beard," which is a tuft of hairs.

The germ of the wheat has a high protein value and is rich in oil which, however, may turn rancid upon exposure to air. About one-fiftieth of the grain is germ. The wheat bran may be

red, yellow or white, the colour, if natural, being no real indication of value.

The preparatory cleaning of wheat for flour production usually yields a variety of weed seeds, plus broken or immature grains which are classed as "screenings." The removal of the main outer coat yields bran, a good quality of which has a chemical analysis almost equal to oats, but its food value is not quite as high as its analysis would suggest. The high value of bran is accounted for by the fact that the protein aleurone grains are torn off with the bran in the milling process.

Once the bran has been removed, the remainder of the milling offals are not so sharply defined, a considerable number of names being applied by different people to different products. Commonly, the terms middlings, parings, sharps, pollards, toppings, shorts, may be met with, but some attempt at standardization has been made in the institution of "weatings" and "superfine weatings." It should be noted, too, that the term "offals" is officially used as defining a product containing not more than 4 per cent. of vegetable matter other than wheat, extracted from wheat in the process of cleaning.

Weatings have a guaranteed fibre content of not more than 5.75 per cent., superfine weatings of not more than 4.5 per cent.

A list of weed seeds likely to be contained in wheat screenings is given in "Flour Milling Technology," by Leslie Smith, and includes corn cockle, black bindweed, bur parsley, mellilot, vetches, wild radish, darnel, buckwheat, garlic, charlock, corn crowfoot and quail corn.

Composition of Wheat and By-Products

	Wheat. Per cent.	Bran. Per cent.	Fine Middlings. Per cent.
Water	13.0	13.2	13.0
Crude protein	13.0	14.1	17.0
Ether extract	2.0	3.7	4.2
Soluble carbohydrates	68.0	56.0	60.8
Fibre	3.0	7.2	2.3
Ash	2.0	5.8	2.4
Bushel weight	60 lb.	19 lb	

Barley

The spikelets of the barley ear are arranged in six, four or two rows up the central stalk; the two-row type is now the more common.

The grain in commerce is spindle shaped and the flowering glume by which it is covered bears five distinct ribs. The central rib of the grain as harvested is extended in a long awn which is broken off in threshing.

The kernel is ordinarily of a buff colour and good barley should have a bushel weight of about 55 lb. The best barley is used for malting, and feeding barley may have a bushel weight as low as 42 lb.

The harvesting times of the principle exporting countries are as follows :

	Harvest.	Earliest Arrivals.
Russia	June-July	October-November.
U.S.A.	June-July	September-October.
Canada	July-August	October-November.
Argentine	December-January	March.

The composition of barley is as follows :

	English. Per cent.	American. Per cent.
Water	14.0	10.80
Crude protein	12.0	10.69
Ether extract	2.0	2.13
Soluble carbohydrate	64.5	69.90
Fibre	5.0	4.05
Ash	2.5	2.43

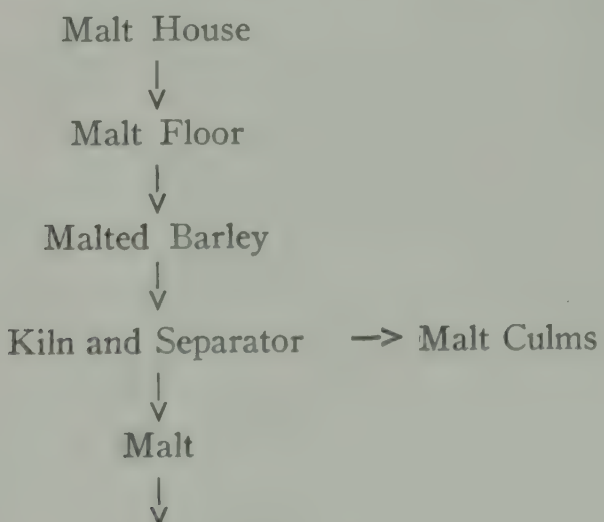
Barley meal is the whole grain coarsely ground and, like other ground grains, it does not keep well, while pot barley and pearl barley is grain less husk and bran. Pearl barley is more polished than pot barley.

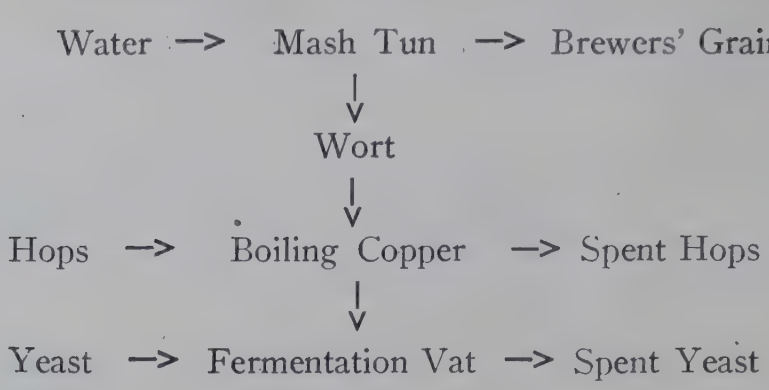
From the preparation of pearl barley for human consumption is obtained coarse, medium and fine dusts. The fine dust is the best of the three and may contain some of the chalk used in polishing the grain. Barley feed, a mixture of the three pearl barley dusts has, according to Linton, a composition of :

	Per cent.		Per cent.
Water	10.0	Fibre	8.0
Protein	12.7	Soluble carbohydrates	61.7
Ether extract	3.4	Ash	4.2

By-Products from Brewing

It has already been stated that the best barley is used for malting, and this process yields a number of valuable by-products whose occurrence may be noted in the following process diagram :





The germination and sprouting of the barley on the malt floor is allowed to continue until the plumule and radicle of the seed have grown to about one inch long, when they are fed to the kiln, after which process the sprouts fall off to form the familiar aromatic light brown product known variously as malt culms, coombs, cummins, sprouts, etc. Malt sprouts have a variable composition, but the following figures are a fair average:

	Per cent.		Per cent.
Water	10.0	Soluble carbohydrates	45.0
Protein (crude)	23.0	Fibre	12.3
Ether extract	2.2	Ash	7.5

Brewers' grains as rejected from the brewery are in the form known as "draff," which may contain 70 to 90 per cent. of water. In this form, their keeping quality is poor and their use purely local. The dehydrated product, known as dried grains, has good keeping qualities, with an average composition of:

	Per cent.		Per cent.
Water	9.5	Soluble carbohydrates	42.3
Protein	20.9	Fibre	15.9
Ether extract	7.0	Ash	4.7

Distillers' grains are similar to brewers' grains, but usually contain more protein. The raw materials used in distilleries may be maize, potatoes, rye, rice and molasses, as well as barley. The resulting grains may be slightly acid. Porter grains also are very similar to brewers' grains, but have a distinctive brown colour.

The brewery by-product, spent yeast, may be considered here, and its chief value lies in its protein content of 48 per cent., mineral content of 10 per cent., as well as being a rich source of the vitamin B complex. In appearance, it is flaky and of cream to brown colour, with a bitter taste.

Rye

Rye is not recognized as a popular food and, in a new condition, may actually be dangerous. The kernel is more slender than wheat and tapers more towards each end; it also has a less inviting colour, being dirty brown or green-brown.

Very little rye is grown in England and is usually cut green for local consumption. Composition :

	Per cent.		Per cent.
Water	13.0	Soluble carbohydrates	70.0
Protein (crude)	12.0	Fibre	2.0
Ether extract	2.0	Ash	2.0

Most cereals are liable to attack by the poisonous fungus, ergot, but rye is particularly susceptible. In the resting stage, the fungus ergot forms a hard, slightly curved body of a dark purple or black colour, and may attain the length of about an inch. It may be seen protruding between the palea of the flower of the host plant. The actively parasitic stage of ergot is known as the "honey dew" stage, from which some idea of its appearance can be formed.

Maize

A most important cereal to the compound and provender miller; it is not grown in this country except for green fodder. The grain is imported, chiefly from North and South America, North and South Africa, and India.

For our purposes, there are two distinct types of maize, the dent or flat maize and the flint or round maize. Flint maize, as its name implies, is the harder variety, whilst the dent maize has a soft, starchy part of the endosperm reaching the full length of the grain which, as it dries, shrinks to form the characteristic indentation. Around the soft starch of the dent maize is found a hard, translucent material and it is this horny substance which constitutes practically all of the flint maize endosperm. The grain may be coloured yellow, orange, white or red, but colour has little bearing on nutritive value.

Maize is essentially a carbonaceous material, having a composition of :

	Per cent.		Per cent.
Water	13.0	Soluble carbohydrates	69.0
Protein (crude)	10.0	Fibre	2.0
Ether extract	4.0	Ash	1.5

The maize kernels, each in a chaffy cup, are arranged on the growing cob in double rows. The structural composition of the grain was shown when the various parts of a seed were discussed in an earlier lesson. Maize varies from wheat in that the bottom lobe of the scutellum is much larger than the top lobe.

The maize germ is, of course, very rich in oil, the yellow variety having a composition of :

	Per cent.		Per cent.
Water	11.29	Soluble carbohydrates	49.25
Protein	13.34	Fibre	4.0
Ether extract (fat or oil)	18.0	Ash	4.0

Maize is commonly flaked, an increase in digestibility being claimed for maize so treated, and flaked maize may have a composition of :

	Per cent.		Per cent.
Water	11.0	Soluble carbohydrates	72.5
Protein	9.8	Fibre	1.5
Ether extract	4.3	Ash	0.9

Maize, in common with other principal cereals, is imported into this country all the year round, but principal exporting countries harvest times are as follows :

Argentine : February-March. New crop begins to move early in March.

South Africa : April-August. New crop begins to move early in July.

Europe : September-October. Arrives in England in December.

Rhodesia : June-August. Arrives in England in October.

U.S.A. : October. Arrives in England in January-February.

Maize meal or Indian meal is the whole maize grain ground up without any part of the kernel removed. As it contains the oily germ, it is inclined to go rancid and develop an unappetizing odour. Ground cereal products, when stale, may become injurious to livestock.

The separated germ of maize is often crushed in a similar manner to oilseeds, to obtain the contained oil, leaving a residual cake. In the manufacture of starch and cornflour, the germ is removed from the kernel in the preliminary stage, and in this process it is desirable to separate the germ with as little adhering starch as possible; this is usually effected by flotation.

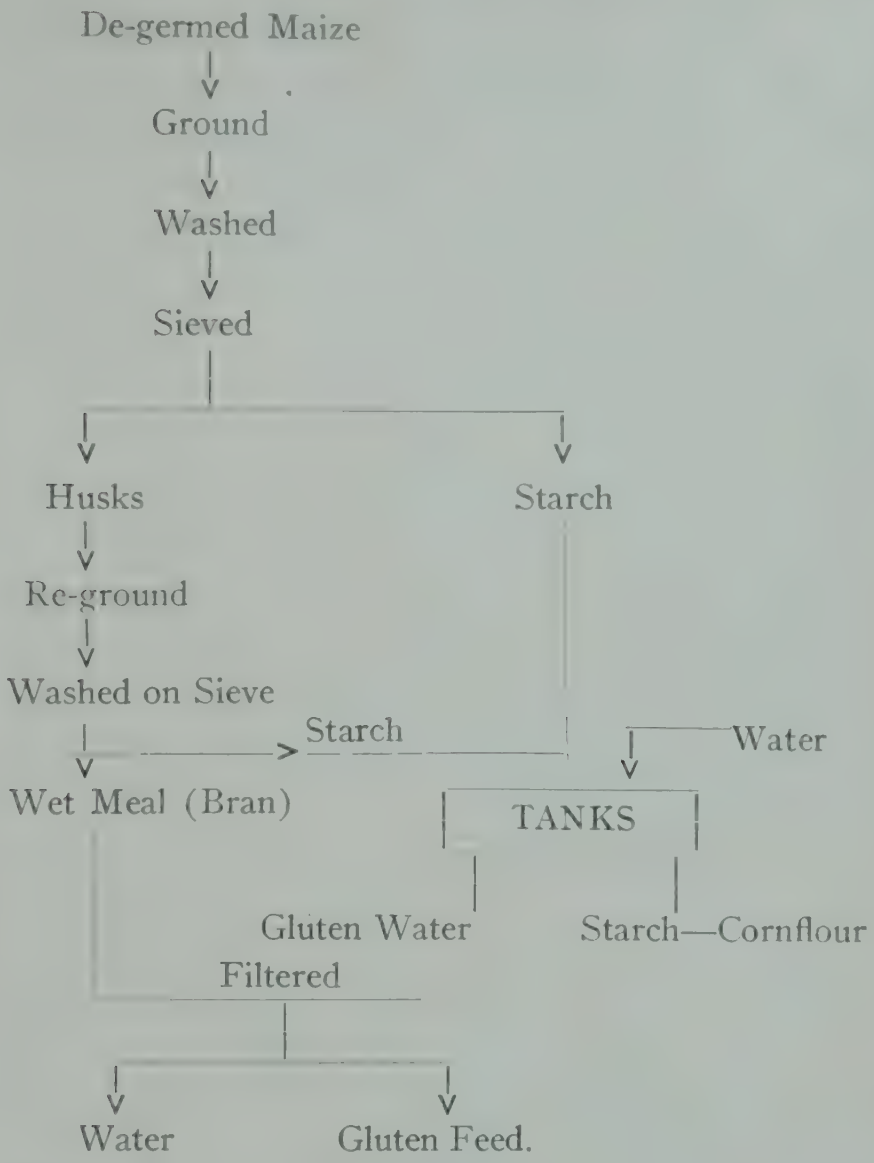
In the dry method of separation a percentage of starch goes along with the germ. This results in the composition of maize germ, cake or meal, varying with its origin.

*R. G. Linton gives the following figures for the two products :

	Maize Germ Meal from starch works. Per cent.	Maize Germ Meal from dry process. Per cent.
Moisture	11.5	12.0
Protein	21.5	10.0
Fat	10.0	11.0
Starch	18.0	23.8
Other carbohydrates	31.5	35.0
Fibre	6.0	7.0
Ash	1.5	1.2

The manufacture of starch from maize also yields a further by-product of use to the compound miller, namely, maize gluten feed, whose origin is indicated in the following chart :

* "Animal Nutrition and Veterinary Dietetics," R. G. Linton and H. Williamson.



Although the most common product is the maize gluten feed, or Paisley meal, the bran and the gluten may be dried and sold separately as maize bran and maize gluten meal respectively. In the manufacture of hominy or maize grits, the finer meal produced is sold under the name of hominy chop.

Representative analyses of the maize by-products are :

	Water	Protein	Oil	Sol. carbo-hydrates	Fibre	Ash
Bran	11.8	8.9	4.2	62.0	11.7	1.9
Hominy chop	10.1	10.6	8.0	64.3	4.4	2.6
Gluten meal	9.1	35.5	4.7	47.5	2.1	1.1
Gluten feed	10.4	23.5	3.4	56.7	3.5	2.5

Rice

The rice kernel is almost entirely used for human consumption, but in its preparation for this purpose, a number of by-products result which play a large part in the compound miller's raw materials.

The most important by-product is rice meal, which is a mixture of bran, germ, and some of the endosperm removed from the kernel in the process of polishing for human consumption. The composition is likely to vary with the source of supply. In some countries, it is the custom to parboil the rice before dehusking and polishing. A typical analysis might be:

	Per cent.		Per cent.
Moisture	9.0	Soluble carbohydrates	49.0
Protein	13.0	Fibre	6.0
Fat	14.0	Ash	9.0

In view of the variable nature of rice meal, it should always be bought on analysis.

RICE MEAL is a rich source of vitamin B_1.

RICE SLUMP is a material left over from the manufacture of rice starch.

RICE POLISH or POLISHER MEAL is the residue from the rice polishing process.

RICE BRAN is the seed coat removed preparatory to polishing.

Remembering the variable nature of the products, the composition of rice by-products on a dry matter basis may be taken as:

	Bran Per cent.	Polisher meal Per cent.
Protein	13.31	16.0
Fat	10.13	17.0
Soluble carbohydrates	46.65	54.0
Fibre	18.3	6.0
Ash (total)	12.61	7.0

Consideration of the foregoing analysis shows that rice meal has considerable feeding value, but the effect of its high oil content on keeping qualities should be borne in mind. Its high oil content, together with the floury nature of the meal, presents the miller with a problem in handling and storage, particularly of bulk quantities.

Rice meal and bran shipments from Burma normally take place from February to early May, but smaller shipments may continue up to October. Small quantities of rice bran are exported from the Dutch East Indies, the heaviest shipments being in August. Rice itself is normally shipped all the year round from India. From Indo China, where it is harvested in December, January and February, it is shipped to Europe through the port of Saigon from March to December. The heaviest shipments of rice products from Egypt are likely to occur about February.

Dari

Dari, or white sorghum, a small, globular seed about 4 mm. long is a native of Africa. A red variety is available, referred

to as red dari. Different varieties of the seed are known under the names Kaffir corn, durra and milo. Comparison of the analyses of red and white varieties shows no important variation and average figures may be taken as :

	Per cent.		Per cent.
Water	13.0	Soluble carbohydrates	69.0
Protein	11.0	Fibre	1.5
Ether extract	4.0	Ash	1.0

Chief source of white sorghum is the Sudan, whilst a yellow or yellowish brown originates in South Africa.

Millet

True or common millet has been cultivated since prehistoric times in Asia, Northern Africa and Southern Europe. Under the Russian name "proso," it has been introduced into the United States of America. The kernel is about 2 mm. long and nearly 2 mm. broad. It is nearly flat on one side, and on the convex side contains a depression under which is located the embryo. The composition of millet is approximately as follows :

	Per cent.		Per cent.
Water	12.0	Soluble carbohydrates	61.0
Protein	11.0	Fibre	8.0
Ether extract	4.0	Ash	4.0

Buckwheat

Although not a cereal in the true sense, it is commonly classed as such. The three-sided kernel is covered with a hard, fibrous hull of dark brown, dull grey or black colour, and the endosperm is white. The kernel or fruit is classed as an achene and not a caryopsis, the difference being that, in an achene, the pericarp and testa are not fused together as is the case with the caryopsis of true cereals.

Buckwheat is also dicotyledenous, differing in this respect from the monocotyledenous true cereals. An average analysis of American buckwheat yields the following figures :

	Per cent.		Per cent.
Water	12.62	Soluble carbohydrates	69.43
Protein	10.02	Fibre	8.67
Fat	2.24	Ash	2.02

The Leguminous Seeds, or Pulses

The legumes from the feeding point of view are characterized by a high protein and well balanced mineral content. The family lends itself to division into two groups, peas and beans.

Schedule IV of the Fertilizers and Feeding Stuffs Act specifies the species of beans from which bean meal may be manufactured as : " (1) *Faba vulgaris*, or any of its varieties known commonly as 'horse bean,' 'field bean' or 'broad bean,' and (2) *Phaseolus vulgaris*, the 'true haricot bean' or any of

its varieties, white or coloured." Other varieties of *Faba vulgaris* are the New Zealand bean, the China bean and the Algerian bean.

R. G. Linton* expresses the opinion that the dirt which so frequently accompanies China bean imported into this country is a factor responsible for the outbreaks of anthrax associated with the feeding of bean meal.

The Ministry of Agriculture bulletin "Rations for Livestock" gives the composition of beans as :

	Per cent.		Per cent.
Water	14.3	Soluble carbohydrate	48.5
Protein	25.4	Fibre	7.1
Oil	1.5	Ash	3.2

Note should be made of the black, white, red and brown varigated Java bean, which contains a highly poisonous substance. Other varieties of the Java bean, like the white Burma, are free from poisonous constituents.

Bean pickings, as the name suggests, are the small or damaged seeds screened from the main crop.

PEAS.

In feeding value, peas are not very dissimilar from beans.

Pea meal is defined by the Fertilizers and Feeding Stuffs Act as : " the meal obtained by grinding commercially pure peas, as grown, of varieties of *Pisum sativum* or *Pisum arvense*. Varieties cultivated in England are Prussian Blue, Dun, Maple (field pea) and Common Grey. The composition of peas is very similar to that of beans.

LOCUST BEANS.

A familiar material in the compound mill, consisting of thick, fleshy pods containing a number of hard, red seeds of a flattish, oval shape, each occupying its own cell and separated from the next seed by pulpy ribs.

The characteristic feature of the pod is its high sugar content which, in the new season or " green " locust, may afford considerable difficulty in grinding. The red seeds contained in the pods are very hard and must be well ground before any of their fairly high protein content can be made available.

Whilst the seeds and pods can be used separately, it is more common to find them ground together to yield a material of the following composition :

	Per cent.		Per cent.
Water	14.0	Soluble carbohydrate	69.0
Protein	6.0	Fibre	7.0
Oil	1.75	Ash	2.25

Of the soluble carbohydrate, up to 58 per cent. may be in the form of sugar; that is to say, the sugar content of the whole bean may be 40 per cent.

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* Professor of Hygiene and Vice Principal, Royal Veterinary College, Edinburgh.

LENTILS.

Lentils have a considerable use as food for human beings, but may be fed as a ground-up straight meal to cattle. Lentil bran consists of the husks of the lentils rejected in the preparation of the seed for human consumption.

GRAM (CHICK PEA).

This brown coated seed is a concentrated nitrogenous food containing from 20-24 per cent. protein. It is imported into this country from India, and samples may be found infested with weevils.

Oilseed Residues

Oilcakes, as a class, constitute the most concentrated of the foods used for feeding to livestock. The manner of producing the various forms of oilcake was referred to in an early lesson, and a description of the more important residues was given.

The original oil bearing seeds are not of immediate interest, except insofar as they may possess important characteristics which may be transmitted to the residual cake, or as their method of growth or their place of origin may involve the presence of undesirable substances in the cake. For those who are interested in the original oilseeds, reference should be made to the notes on the oilseed crushing industry.

Palm kernel press cake and cake meal produced in this country have an average composition of :

	Per cent.		Per cent.
Water	11.0	Soluble carbohydrate	46.0
Protein	19.0	Fibre	14.0
Oil	6.0	Ash	4.0

The criticism of having poor keeping qualities formally levelled at this cake is avoided by storing in dry conditions and, as far as possible, keeping in cake form until it is to be used. Noticeable impurities in cakes made in this country are not likely to be present, but imported cakes, as well as having a higher oil content, say 10 per cent., may contain increased fibre due to the presence of a proportion of the hard outer shell of the kernels. Babassu nuts are also commonly found with palm kernels and may be processed by less careful oilseed crushers.

Extracted palm kernel meal has an average composition of :

	Per cent.		Per cent.
Water	12.0	Soluble carbohydrate	48.0
Oil	2.0	Fibre	16.0
Protein	19.0	Ash	4.0

COCONUT (COPRA).

The dried kernel of the fruit of the coconut palm, after having its high oil content reduced by pressure or solvent extraction, yields the sweet smelling, palatable coconut cake. Coconut cake absorbs moisture very readily and should, therefore, be stored in a dry atmosphere. The absorption of water by the cake is accompanied by considerable swelling.

The cake, either in slab form or ground to form meal, has an average composition of :

	Per cent.		Per cent.
Water	11.5	Soluble carbohydrate	42.0
Protein	20.0	Fibre	13.0
Oil	7.5	Ash	6.0

The extracted meal has a very much lower oil content, approximately two per cent.

GROUND NUT.

Ground nuts, variously known as pea nuts, earth nuts and monkey nuts, after processing in the oil mill, yield a residue which may be in one of a variety of forms depending upon : (a) The particular de-oiling process used, and (b) the amount of shell which is removed from the nut before processing. The three possible methods of processing which have been referred to previously are : pressing, expelling, and extracting.

The quantity of husk present in the residue is indicated by the use of the terms undecorticated, semi-decorticated and decorticated. Undecorticated cake contains the whole of the nut shell, decorticated cake contains no shell or very little, whilst semi-decorticated indicates a mid way shell content, although the term semi-decorticated has very vague implications and products described as such are more likely to be nearly undecorticated than otherwise.

There is a wide variation in the appearance of ground nut cake (slab), the near-white appearance of some decorticated samples contrasting strongly with the chocolate brown of the imported Rangoon or " Jungle Nut " cake. Careful watch should be kept on ground nut cake for the presence of castor seed residue from the inadvertent processing of the castor bean along with the ground nuts. Ever increasing quantities of ground nuts are being processed in expellers, resulting in a cake in the form of the familiar " curves " or " flakes."

Compositions of decorticated and undecorticated products are as follows :

Decorticated :

	Per cent.		Per cent.
Water	10.0	Soluble carbohydrate	23.2
Protein	46.8	Fibre	6.5
Oil	7.5	Ash	6.0

Undecorticated :

	Per cent.		Per cent.
Water	10.0	Soluble carbohydrate	22.0
Protein	30.0	Fibre	23.0
Oil	9.0	Ash	6.0

Undecorticated extracted :

	Per cent.		Per cent.
Water	8.0	Soluble carbohydrate	29.0
Protein	32.0	Fibre	23.0
Oil	2.0	Ash	6.0

COTTONSEED.

Cottonseed residues present a similar range to ground nut, with the additional sub-division occasioned by the two types of seed known as Egyptian and Bombay. Considerable quantities of cotton cake are exported from Brazil.

The undecorticated cake contains a large amount of fibre, and presents a woolly appearance and a darkening of colour when compared with the bright yellow of good quality decorticated cake. Bombay cake normally presents a dull brown colour.

Average figures for cottonseed products are given in the following table:

	Water %	Protein %	Oil %	Sol. carbohydrate %	Fibre %	Ash %
Cotton Cake:						
Bombay	12.0	20.0	5.0	35.0	22.0	6.0
Brazil	11.0	27.0	5.4	27.0	25.0	4.6
Egypt	12.0	23.0	5.0	33.0	21.0	6.0
Decorticated	10.0	41.0	8.0	26.0	8.0	7.0

Undecorticated cotton cake is inclined to present difficulties in grinding if the lint content is at all high.

LINSEED.

Linseed cake is one of the most highly prized cattle foods, although linseed contains a cyanogentic glucoside which, by the action of a contained enzyme, produces the poisonous prussic acid under certain conditions. Fortunately, all the acid is not freed at once, and if the cake is properly handled, no free acid is produced at all. By using the cake in compound mixtures, the amounts present are obviously diluted.

Good linseed cake should be of a reddish brown colour and of a hard texture.

LINSEED CAKE MEAL.

This is the cake ground up and will have similar characteristics to the cake.

LINSEED MEAL.

Is the original seed ground into meal form and is particularly valuable for sick animals.

COMPOSITIONS.	Water %	Oil %	Protein %	Sol. carbohydrate %	Fibre %	Ash %
Linseed	7.0	36.0	23.0	23.0	7.0	4.0
Cake (English)	11.0	9.5	29.5	35.6	9.1	5.3
Meal (extracted)	12.0	3.0	36.0	34.0	9.0	6.0
Cake (foreign)	11.0	10.0	32.0	32.0	9.0	6.0

SESAME.

Variously known as gingelly, jinjilli, sem-sem, beniseed, etc. The seed itself may be white, reddish or black, and the colour of the cake will obviously be affected by the seed used. The cake has good keeping qualities. Poorer qualities of cake may

have an excessive fibre content. Compositions of cake and meal are as follows :

	Per cent.		Per cent.
Sesame Cake (English) :			
Water	9.0	Soluble carbohydrate	21.0
Protein	44.0	Fibre	5.0
Oil	12.0	Ash	9.0
Sesame Cake (French) :			
Water	8.5	Soluble carbohydrate	16.5
Protein	38.0	Fibre	17.0
Oil	11.0	Ash	9.0
Sesame Meal (extracted) :			
Water	6.0	Soluble carbohydrate	27.0
Protein	46.0	Fibre	8.0
Oil	2.5	Ash	10.5

RAPE.

The seed itself is small, round, dark coloured and smooth and its oil has been used for centuries as an illuminant. The residual cake bears a resemblance to linseed, but freshly broken surfaces show a characteristic greenish colour. Rape is one of the small group of raw materials which needs careful usage as a food, because of harmful constituents. Rape seed is likely to be contaminated with mustard seed.

When used in compound food the dangerous possibilities of rape cake are reduced, but suspect cake may be roughly tested by moistening and heating in a closed vessel and then testing for mustard smell. Composition :

Cake :	Per cent.		Per cent.
Water	8.5	Soluble carbohydrate	25.5
Protein	35.5	Fibre	8.5
Oil	9.5	Ash	12.5

NIGER SEED CAKE.

A black coloured cake made from the fruit of *Guizotia oleifera* (*abyssinica*), which is a black, lustrous, cylindrical seed, about 0.2 inch long by about 0.1 inch broad. Composition :

Cake :	Per cent.		Per cent.
Water	11.0	Soluble carbohydrate	23.0
Protein	32.0	Fibre	18.0
Oil	6.0	Ash	10.0

SUNFLOWER.

Imported sunflower cake is inclined to contain a fairly high proportion of indigestible fibre, but a good decorticated cake will have an approximate composition of :

	Per cent.		Per cent.
Water	10.0	Soluble carbohydrate	20.5
Protein	37.5	Fibre	12.0
Oil	14.0	Ash	6.0

Sunflower cake is one of the few oilseed residues the raw material for which can be grown in this country.

Soya Bean.

The last in our present list of oilseed residues is not, of course, the least in importance; on the contrary, soya bean products are becoming of ever-increasing importance. The cake and meal contain no harmful constituents, and are highly concentrated nitrogeneous materials. Composition:

Cake:	Per cent.		Per cent.
Water	13.0	Soluble carbohydrate	26.5
Protein	43.0	Fibre	5.5
Oil	6.0	Ash	6.0
Extracted Meal:			
Water	12.0	Soluble carbohydrate	31.0
Protein	44.0	Fibre	5.5
Oil	1.5	Ash	6.0

Foods of Non-vegetable Origin

These include materials like fish meal, meat meal, meat and bone meal, bone meal, dried blood, milk powder and whey.

The production of meals from fish and animal flesh and bones involves the removal of surplus moisture and oil from those parts of the carcases which are not used for human consumption. The oil may be removed by a wet rendering process, by a dry rendering process, or by solvent extraction.

The wet process may consist of simply boiling the bones in hot water and decanting off the greasy water, or it may involve the use of a "digestor," that is, a pressure vessel which is filled with the flesh and bones, and into which is injected live steam. The vessel has a perforated bottom plate, through which the fat and condensed steam percolate into a receiving vessel. The degreased meat tissue in the pressure vessel or autoclave is discharged and cooled, although a further drying may be necessary.

The dry method involves the use of a jacketted cylinder, in which the jacket heat dries off the moisture and disrupts the grease cells, freeing the contained grease. Most of the released grease is drawn off and the meat residue is then put into a centrifuge which removes most of the adhering grease.

The extraction process is very similar to that used for oilseeds. The extraction pot is, however, steam jacketted. The jacketted heat is used to vapourize off the solvent with a moisture/fatty suspension which is led to a cooler in which the moisture, fat and solvent separate out as three fractions. Once the solvent has been evaporated, the jacketted steam is shut off and live steam is introduced to remove the traces of solvent which still remain on the meat.

After drying out, the meat is ground into meal.

Meat meal of good quality should have an approximate analysis of:

	Per cent.		Per cent.
Water	11.0	Oil	9.0
Protein	75.0	Ash	4.0

Some care must be exercised over analysis figures of the animal products. By law, there shall be not less than 55 per cent. protein nor more than four per cent. salt. This is on a fat content of about 13 per cent., and the moisture content about 11 per cent., but actually, meat meal is more likely to have a protein content of over 70 per cent. "Rations for Live Stock" gives :

	Per cent.		Per cent.
Water	10.8	Oil	13.2
Protein	72.2	Ash	3.8

but meals from the extraction process may have a fat content as low as three per cent. Probably a good figure for animal feeding is about nine per cent. of oil.

The introduction of a proportion of bone into the meal produces meat and bone meal. The bone introduces a valuable mineral content into a mixing and an excess of bone can be guarded against by ensuring that the protein content is higher than the obligatory 40 per cent.

Bone, by itself, is ground to form bone meal. The bones may be either raw or degreased. It should be distinguished from sterilized bone flour and also from low temperature bone meal produced from healthy animals. A Government Order of 1932 requires that all material of animal origin must be exposed to a temperature of not less than 100° C. for a period of at least one hour. But licences are issued to approved manufacturers exempting them from this requirement under certain stringent conditions and what is called "low temperature" meat meal, bone meal or blood meal are produced. The maximum temperature in this process is 72° C. and the resulting products have a higher nutritive value than the high temperature product.

STEAMED BONE FLOUR.

Used as a source of calcium and phosphorous, and to a lesser extent, magnesium.

FIBRENOGEN MEAL.

Blood dried at low temperature.

COD LIVER OIL.

The feeding value of cod liver oil was recognized long before scientific research discovered the existence of vitamins.

Before the war, British cod liver oil production was unexcelled anywhere. The liver of the codfish, in good condition, contains about 80 per cent. of oil, and being in such abundant supply, little more than simple steaming is required to liberate it. Originally the oil was obtained for medicinal purposes by

allowing it to run away during a process of putrefaction, and although this did not affect the vitamin-content, the oil was nauseating. This was largely responsible for the general idea that cod liver oil is essentially sickening and unpleasant to take. Under modern methods of production, good cod liver oil has a delicate, oyster-like flavour.

The specific gravity of the oil varies from 0.922 to 0.929. Cod liver oil does not keep well when exposed to the air, and should not be left lying around in open containers. About half the value of cod liver oil is in its vitamin content, the remainder being in its value as a fat. In normal times, the supply of cod liver oil is ample, but if a scarcity should arise, adulteration, which may be easily effected, should be guarded against.

MILK PRODUCTS.

Liquid (cows) milk has an approximate composition of :

	Per cent.		Per cent.
Water	87.4	Protein	3.4
Fat	3.7	Ash	0.75
Sugar	4.75		

In its dried state, milk forms a useful addition to compound feed ingredients, and the milk powder may be produced from whole milk or from milk from which most of the fat has been removed. The space occupied by the dry powder is only about one-tenth of that occupied by the original liquid milk, and the moisture content is likely to be about 8 per cent.

The two common methods of drying are: (1) the roller, and (2) the spray.

ROLLER DRYING.

The drying of milk has very little effect upon its nutritional value, the chief feature being a drop in vitamin "C" content. Drying has, however, a marked effect upon bacterial content, but there is no certainty that tuberculosis germs are destroyed; on the other hand, there are no records of the germ having been found in dried milk. Dried milk of good quality, 8 per cent. moisture and carefully packed, should keep for an indefinite period.

WHEY.

This is the fluid left behind after the clotting of milk for cheese manufacture; its food value is not high. After heating and drying, it cools to a hard cake which is easily ground. The colour may be brown. It is hygroscopic, but keeps well if properly packed.

Miscellaneous

COCOA RESIDUES.

Consist of : (1) The cake from the pressing of the fermented seeds of the cocoa tree during the manufacture of beverage

cocoa, chocolate, etc.; (2) all the shells, or husk meal as it is called when ground. Both are unpalatable substances and contain the poisonous "theobromine," so that cocoa by-products may be dangerous foodstuffs.

TAPIOCA FLOUR (Manioc Meal, Cassava Meal).

A by-product of the manufacture of starch from the cassava root is made in a number of grades, the best of which has an average composition of :

	Per cent.		Per cent.
Protein	2.06	Fibre	2.83
Oil	0.54	Ash	2.45
N.F.X.	92.12		

DRIED GRASS.

Young grass, cut and dried, has of recent years become recognized as a concentrated nitrogenous cattle food having a high biological value with an analysis, on a dry basis, of :

	Per cent.		Per cent.
Protein	18.0	Fibre	22.0
Ether extract	3.0	Ash	11.0
Soluble carbohydrate	46.0		

The analysis varies with the time of cutting as well as with the variety of grass. The moisture content of the grass leaving the drier may be as low as 2 per cent., a figure which may increase up to 10 per cent. during storage. A considerable part of the fibre content is of a digestible character.

The Grass Driers' Association have suggested the following classification of dried grass :

	Protein. Per cent.		Protein. Per cent.
Grade I.	17 or over.	Grade III.	12-14
Grade II.	14-17		

CHAPTER XVIII.

SEQUENCE OF PROCESSES AND GENERAL LAYOUT

The word "process" is so convenient to describe all sorts of activities that it is popularly used in rather a loose manner, and it is desirable that it should be used rather more discriminately. It is suggested that the use of the word process might be reserved to describe a complete group of operations, e.g., the manufacture of finished cubes, meals, flaked maize, might be considered as processes. That is to say, the complete manufacture of the finished product constitutes a process.

From this, it will be seen that most processes consist of a number of operations, although in certain cases, one single

operation may constitute a complete process, as, for instance, the manufacture of a straight meal from an oilcake.

Processes then are built up of a number of operations. These operations may be of two kinds, firstly, those operations which modify the characteristics of the materials being processed, and secondly, those operations which alter the location of the material. The first kind of operation may be described as a process operation, and the second kind of operation as a handling or conveying operation. Process operations are dictated by the essential needs of the process, whereas handling operations are dependent mainly upon economic consideration or the convenience of site, location and layout.

Consideration may now be given to the range of processes, which is indicated by the range of complete manufactured products which are different from one another. In this application, a process is only different from another process by virtue of the fact that it is composed of different operations and no difference, of significance, may be attributed between process by virtue of difference in the materials being handled.

For example, the difference between the manufacture of dairy meal and poultry pellets arises from the fact that poultry pellets require process operations other than those required in the manufacture of dairy meal. The fact that the ingredients of dairy may be different from those of poultry is of no significance, except in so far as that difference may involve the use of different operations of an essential character. From this point of view, the following processes may be considered :

Cube manufacture.
Compound meal manufacture.
Flaked cereals manufacture.
Straight meal manufacture.
Kibbled products.
Crushed products.
Clipped cereal manufacture.
Molassed meal manufacture.

All these processes are composed of one or more of the following operations :

Grinding.
Cutting.
Rolling.
Seiving.
Mixing.
Cooking.
Hulling.
Kibbling.
Cubing.
Cooling.
Humidifying (damping).
Clipping.
Aspirating.
Drying.
Proportioning.

We can now consider which operations are essential to which processes :

Cubes :

Grinding.
Proportioning.
Mixing.
Cooking.
Pressing.
Cooling.

Compound Meals :
Grinding.
Proportioning.
Mixing.
Cooking.
Cooling.

Flaked Cereals :
Cutting or Crushing.
Sieving.
Damping.
Cooking.
Flaking.
Drying.
Cooling.

Straight Meal Manufacture :
Grinding.

Grits Manufacture :
Cutting.
Sieving.

Kibbled Products :
Kibbling.
Sieving.

Crushed Products :
Crushing.
Damping
Rolling.

Clipped Cereals :
Clipping.

Molassed Meal :
Hot Mixing.
Cooling.

The packing and weighing of the products is not included in the above, for these are not considered essential to the manufacture of the commodity but are imposed by the commercial conditions attendant upon their sale.

It will be seen that there is a certain amount of elasticity in the use of some of these terms (mixing, sieving, rolling).

The operations included in the foregoing processes are only those that may be considered essential to the process. In other words, these operations are common to all mills. In actual practice, of course, a number of auxiliary operations are performed to produce a better quality of product or to safeguard the machinery from damage, e.g., preliminary cleaning, ferrous material separation, washing, etc.

The number and character of these auxiliary operations will be determined by a number of factors, amongst which will be found : Personal idiosyncrasies of the miller ; source of supply and nature of majority of raw materials used in the mill ; economic efficiency of the mill ; demands of the customer for high quality products ; space available ; and the types of machines used to carry out the essential operations.

CHAPTER XIX.

SEQUENCE OF PROCESS OPERATIONS

To illustrate the incidence of auxiliary operations, consider a hypothetical case of a mill having some facilities for bulk intake and storage, but having the majority of materials received and stored in bags, and follow through the manufacture of compound cubes (Fig. 109).

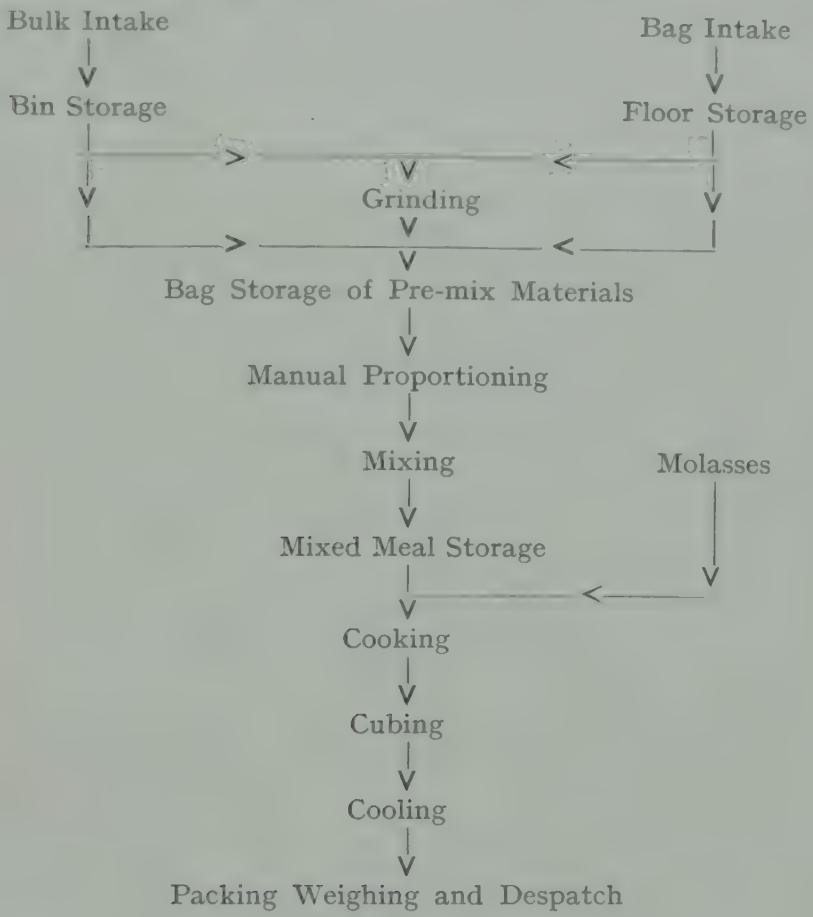


Fig. 109

If raw material received at the mill was always completely free from impurities, then the flow shown would be a practical one, and even allowing for a normal proportion of rubble, the incorporation of a rough intake screen plus the location of magnetic separators at strategic points might be considered all that is necessary. If the number of magnetic separators was to be a minimum, then they would only be fitted prior to those machines which would be damaged by the presence of tramp iron, notably grinders and cubing machines in the flow under consideration.

The protection of grinding machines affords an illustration of the effect upon auxiliary process operation occasioned by the type of machine used for the essential operation. If, for instance, slab cake was broken in two stages, first by a kibbling

machine, followed by a grinder of the "Perplex" type, the incorporation of magnetic separators before the "Perplex" machine must be considered essential, whereas if the cake was broken and ground in a single operation by a swing hammer mill, then no protection to the machine could be afforded by a magnet against tramp iron embedded in the slab cake.

Those operations that have been listed as essential to the process of manufacturing compound cubes are: Grinding, proportioning, mixing, cooking, pressing and cooling. This list makes no mention of storage at any stage, and the function of storage may be appreciated by considering the conditions necessary to allow cubes to be made without storage at any point. In the absence of storage facilities, all the materials required for a mixing would need to arrive at the mill just when they were wanted and at a rate determined by the production capacity of the plant.

Those of the raw materials which required grinding would need to arrive sufficiently in advance of those which did not require grinding, so that the movement of ground material from the grinding plant would coincide with the arrival at the mill of those materials which did not require grinding. The rate of mixing would need to be exactly the same as the rate of cube production and any fault in the process, even a hold up at the weighing stage, would be reflected right back to the transport vehicles, and vice versa; the slightest delay in the arrival of materials would stop the whole plant.

Even if such scheme as this could be considered as a possibility, it will be clear that the cubes produced by such a plant would need to be sold for their "weight in gold" to cover the cost of production. The introduction into the flow of even a nominal amount of storage capacity effects an immediate and remarkable economy. The use, and it might be added the abuse of storage, is not our immediate concern, which is to investigate the proper sequence of process operations, but it will be readily appreciated that the proper position of an operation cannot be determined without some consideration of its function and the contribution it makes to the total process.

The obvious nature of raw materials and finished goods storage may tend to blind students to the important use of intermediate storage upon which depends, to a large extent, the flexibility of a plant with the localization of the effects of an operational fault. This is demonstrated by the use of a storage bin feeding a cubing machine; any temporary stoppage in the machine will not affect the mixing plant whose output can be received by the storage bin prior to the cubing machine.

From the practical point of view, storage is an essential feature of any process flow. Its incidence is determined by the

nature of the machinery used in the process, by the supply of and demand for raw materials and finished products, by the fallibility of machines and their operators, and is always conditioned by the need of maintaining production costs at an economic level. Storage is analyzed as a materials handling operation, but unlike most of the handling operations, is not determined by site and layout of plant. The proper position in the flow of many of the operations is evident at the outset, although minor modifications may be met with in different mills. The introduction of auxiliary operations into the flow almost immediately differentiates one mill from another and enlarging the flow shown we might have the following :

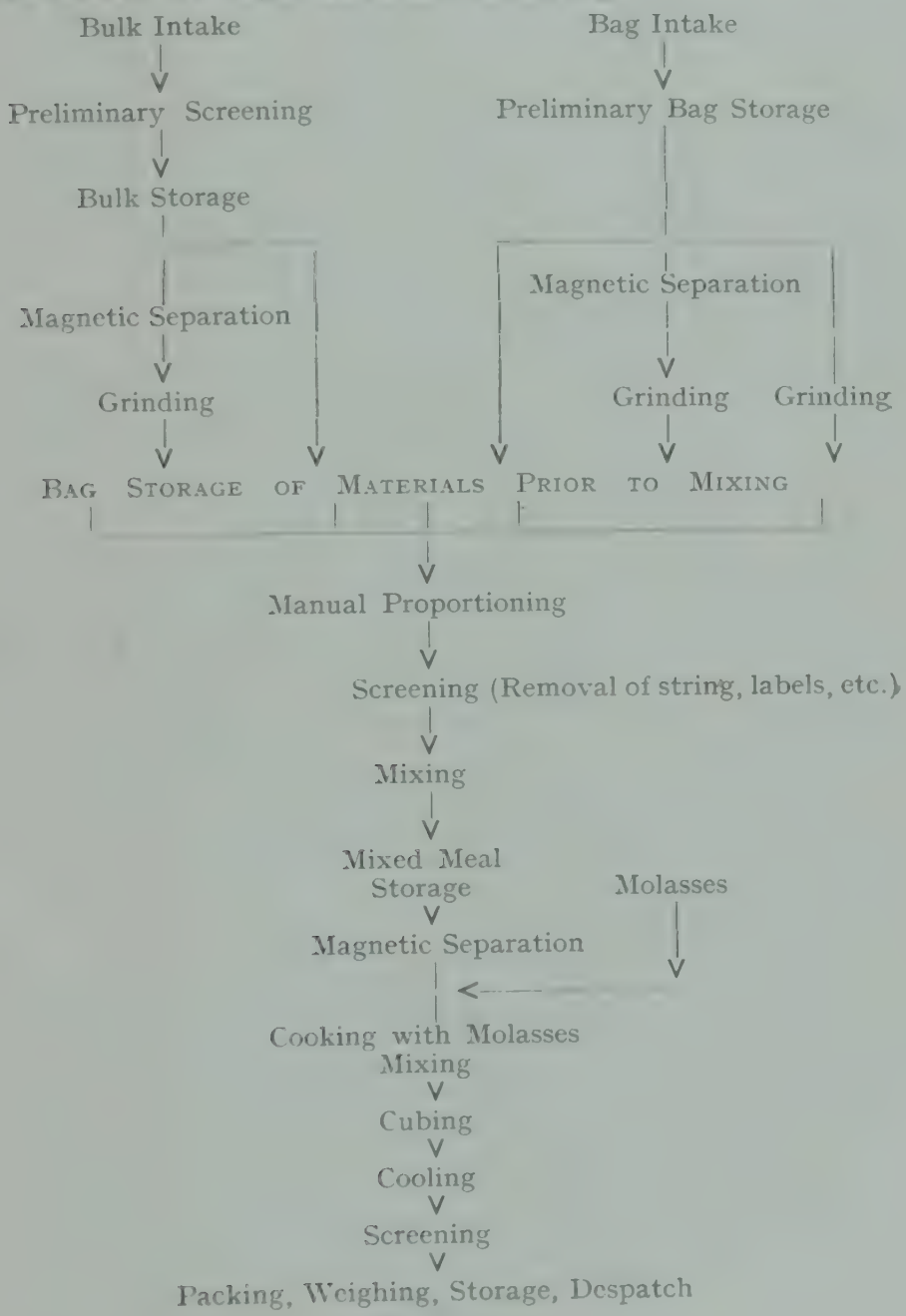


Fig. 110

Avoiding any suggestion that the cube manufacturing flow shown is a good one, the number of auxiliary operations shown must be considered a minimum.

The passing of all bulk material to be ground over a magnetic separator contrasts with the grinding of some bagged material without passing over magnets. The bagged material in question is in slab form, which makes magnetic separation ineffective; on the other hand, all the bulk material to be ground passes over a magnet, because if the particle size of the material is small enough to permit bulk storage, it is small enough to be treated by magnetic separators.

Some of the bulk material will be received in a condition suitable for mixing, and this is sacked off and stored in the vicinity of the mixing plant feed along with the bagged materials that do not need grinding. The proportioned feeding of the various ingredients into the mixing plant is controlled by a chemist, or a "mixer's" charge hand. The stream of proportioned meal is then screened, chiefly to remove string and labels resulting from the opening of bags in the vicinity of the feed hopper, but this screening also serves to remove rubble which may have been present in the material received in bags which has not passed through the mill's grinding section. The mixed meal leaving the intermediate storage bin is cleaned of ferrous material by a magnetic separator which thus protects the following cooking and cubing machinery.

The finished cubes are shown as being screened after cooling, the screenings or tail ends being returned to a point in the flow prior to cubing. Some millers make a point of screening before cooling, whilst others screen both before and after, but at least one of these screenings stages is essential. The point to which the screenings are returned is subject to differences of opinion and circumstance, but economic considerations dictate that it should be as near the cubing machine as possible.

Packing and weighing are not shown in any definite order of priority. It is the practice in some cases to weigh before packing, in others to pack before weighing, and yet in other cases, to do both simultaneously.

Expanding the operation diagram (Fig. 110) to include the major processes flows likely to be found in a compound mill, we find first of all that the part of the diagram up to the "bag storage of materials prior to mixing" is common to all the products, except, of course, straight meals which need not be considered here. The manufacture of cubes and their complementary meals; of calf meal, poultry pellets and meals, and molassed meal from the prepared raw materials is shown in the following diagram, which is only concerned with the operations involved and is not intended to convey the same kind of information as a flow sheet.

To avoid the possibility of confusion, the following example may be considered: Calf meal and, say, dairy cubes, are manufactured in two separate and distinct groups of machines in a mill. The representation of the machinery by a flow sheet would show two separate and distinct flows, indicating that although many of the operations being carried out in the manufacture

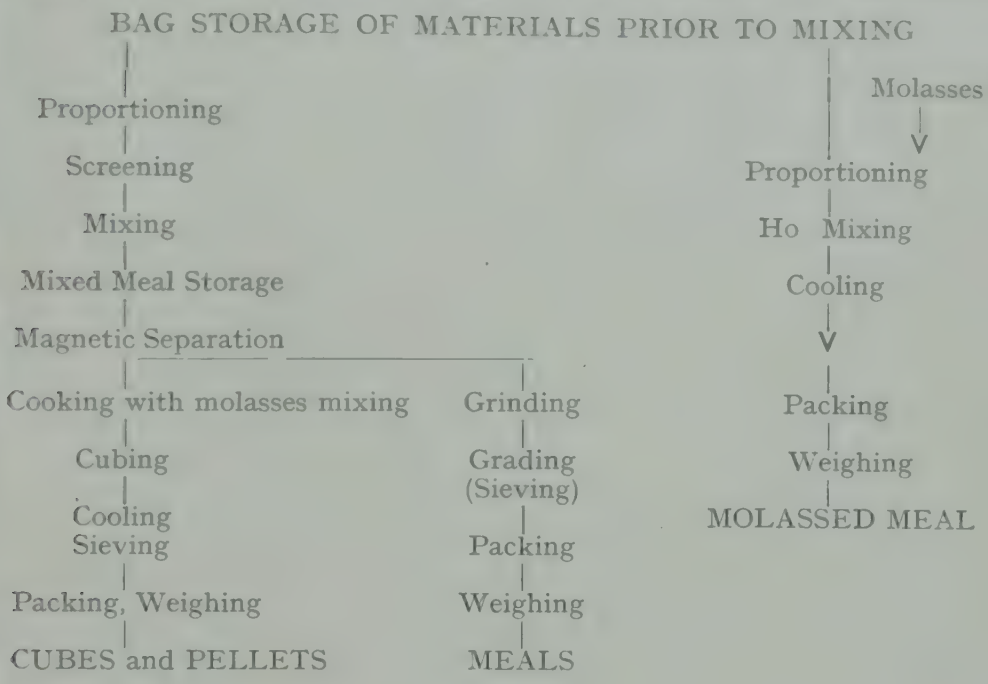
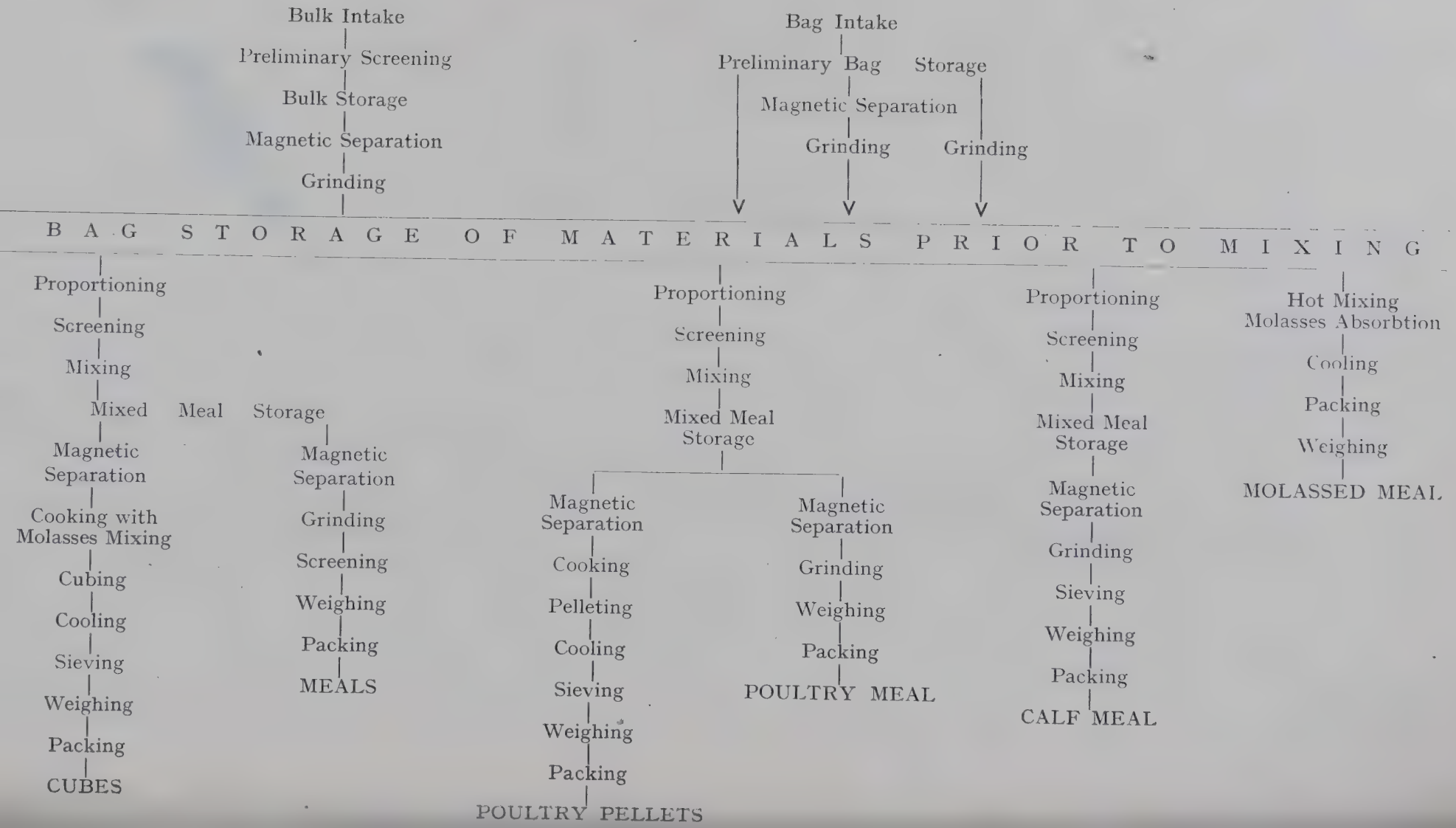


Fig. 111

were identical, the work was being done in two separate plants. The process operation diagram, however, is not concerned with the multiplicity of machines, or even with differences of machines, provided they are carrying out the same operations, and in the example under consideration those operations (not machines) which are common to both the cubes and calf meal would be shown once only and linked in one flow.

The previous and following process operation diagrams must be considered from this point of view.

The basic sequence of compound milling processes are found in Fig. 111. Provender milling sequences can be treated in a similar manner. The next step is to follow the translation of the operational sequence diagram through the flow sheet to the mill layout. The first step in the transition of the sequence diagram to mill layout is the splitting of the diagram into separate flows to coincide with the actual flows in the mill. Before this can be done, however, it is obviously necessary to determine the layout of the mill if it be existing or the intended purpose and capacity of the mill if it is only in the "proposed" stage.


Bulk Intake
Preliminary Screening
Bulk Storage
Magnetic Separation
Grinding
Bag Intake
Preliminary Bag
Magnetic Separation
Grinding
Storage
Grinding
BAG STORAGE OF MATERIALS PRIOR TO MIXING
Proportioning
Screening
Mixing
Mixed Meal Storage
Magnetic Separation
Cooking with Molasses Mixing
Cubing
Cooling
Sieving
Weighing
Packing
CUBES
Magnetic Separation
Grinding
Screening
Weighing
Packing
MEALS
Proportioning
Screening
Mixing
Mixed Meal Storage
Magnetic Separation
Cooking
Pelleting
Cooling
Sieving
Weighing
Packing
POULTRY PELLETS
Magnetic Separation
Grinding
Weighing
Packing
POULTRY MEAL
Proportioning
Screening
Mixing
Mixed Meal Storage
Magnetic Separation
Grinding
Sieving
Weighing
Packing
CALF MEAL
Hot Mixing
Molasses Absorbtion
Cooling
Packing
Weighing
MOLASSED MEAL

be there for the getting. With a proposed design, a variety of factors will influence the number of separate and distinct process plants to be incorporated. The demand for the individual products will have a considerable effect upon the final decision, as will, of course, the range asked for simultaneously.

Consideration would need to be given to:

(1) Maximum anticipated demand for all products.
(2) Proportion of the demand to be satisfied by each product.
(3) The individual and total variation in demand.
(4) Range of products to be manufactured.
(5) Space available.
(6) Variation in characteristics of individual products.
(7) Versatility of the available or chosen machines.

Consideration to these points will be given later, and for the purpose of diagram construction, it will be assumed that it has been decided that cubes and their complementary meals are to be mixed in the same unit, calf meal is to have a separate flow, poultry pellets and meals are to share a mixing unit, and molassed meal, by virtue of its marked difference from other products, demands a unit to itself. The intake, cleaning, preliminary size reduction and prepared ingredient storage to be common to all plants.

This results in the splitting up of the original sequence diagram as shown.

Figure 113 follows the usual practice of flow sheet construction, and shows symbolic representation of the machines used to carry out the operations indicated in Fig. 112. As a flow sheet, it is not completely informative in that no indication of the size of the machines is shown, nor is any capacity stated for the plant units. The diagram does, however, show the development of a flow sheet from the information previously given, and puts into more concrete terms the sequence of process operations and should be looked upon merely in this light.

The configuration of a complete flow sheet requires more information than we are so far in possession of, and involves consideration of plant capacity and choice of specific size and make of machines. This kind of information will become available upon the detailed investigation of the characteristics of the machines that are available to the miller, which study comes later in the syllabus.

In interpreting the diagram, symbols which appear more than once are not named upon each appearance. Whether or not the milling practice represented by the diagram is good or bad in detail, up-to-date or obsolete is of no direct interest. It is sufficient that the sequence of process operations shown are

CHAPTER XX.

PLANT LAYOUT

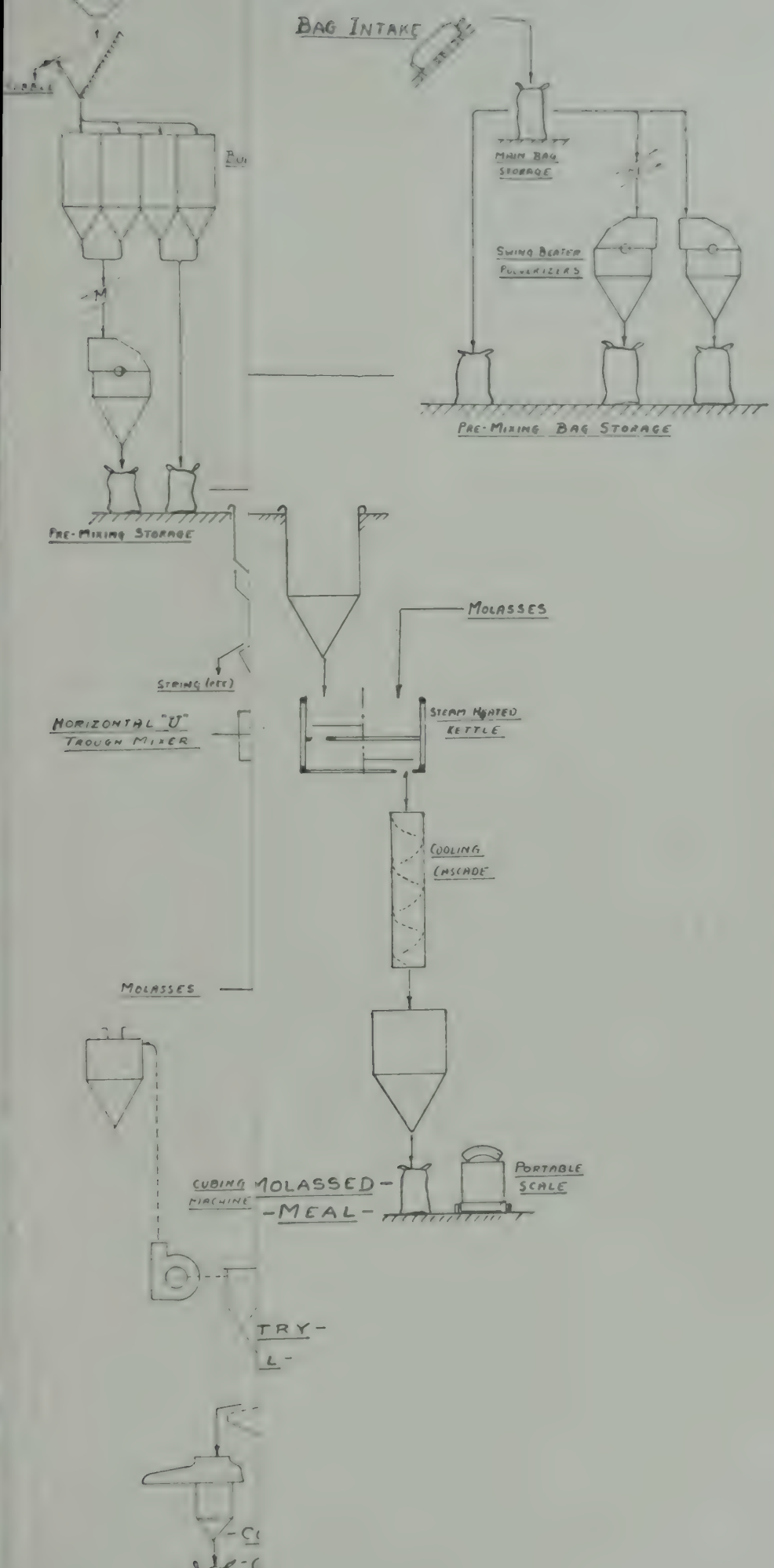
One of the most obvious functions of a flow sheet is its use either in the laying out of a proposed milling plant, or in the visualizing of an existing plant. To this end, the flow sheet should display as much information as possible, consistent with clarity.

The flow sheet diagram (Fig. 113) is intended only to convey information about process sequences. If, however, it is referred to and viewed as conveying information about an actual mill, a multitude of questions immediately arise. What is the size of this grinding machine? How many are there? What is the size of these bins, and how many cubing machines are used? Questions concerning types of machines, if not actual makes, are involved. Machine performances, horse powers, sizes of screens and for plant layout, weight of machines, foundations required, special risks, services of water, steam and air and electricity; information about all these points and others becomes necessary. The flow sheet can supply a lot of this, but obviously, not all.

A useful practice amongst engineers and plant designers is that of having a number of copies of the basic flow sheet, such as that given last week, and use each of the copies to convey a different category of facts, i.e., one flow sheet might give information about electric power, steam or hydraulic services required by the various plant items, whilst another sheet might give the weights of plant when full and when empty, and so on. The layout of a particular mill, as distinct from the flow design, will be influenced by a number of the following factors.

(1) The fitting of plant into existing buildings: The use of existing buildings imposes an immediate restriction upon the possible variations of layout for a given process flow. This restriction is imposed by the size, design and materials of construction of the building, and by the allowable foundation load. The fact of the building's existence also fixes the approaches to the building and depending upon circumstances may fix the fire insurance rate beyond any modification that might have been achieved by judicious plant layout. The layout of plant in a single storey building will obviously be very different from the layout of the same plant in a six storey building. Similarly, differences will arise between the layout in a rectangular building and one consisting of a main block with right angled wings. Variations in material construction of buildings will be reflected slightly in variations in layout. One building may allow higher location of vibrating loads than another.

(2) Whether plant was designed as a complete mill originally or was added to from time to time. In analyzing an existing


BAG INTAKE
MAIN BAG STORAGE
SWING BEATER PULVERIZERS
PRE-MIXING BAG STORAGE
PRE-MIXING STORAGE
MOLASSES
STRING (OFF)
HORIZONTAL "U" TROUGH MIXER
STEAM HEATED KETTLE
COOLING CASCADE
MOLASSES
CUBING MACHINE
MOLASSED -MEAL-
PORTABLE SCALE
TRY-
L-

plant layout, the effect of piecemeal growth will be readily apparent in most cases. Some symptoms of piecemeal growth are :

(a) Disproportionate amount of handling.
(b) Increased difficulty of supervision.
(c) Poor communications.

It should be appreciated, of course, that in favourable circumstances, piecemeal development may compare very favourably with plants designed as complete entities.

(3) The cost of land, where buildings have to be erected, will influence the height of the building for a given floor area, but limitations upon height may be occasioned by the cost of piling in soft land.

(4) Transport facilities : A mill building, connected to other buildings on three sides, will obviously differ considerably in plant layout from a mill that has a water approach on one side, a rail approach on another, and road approaches on the other two sides.

(5) Cost of labour in area of mill : At the present time in factory areas in England, this factor may influence plant design but is not likely to affect layout substantially.

(6) Standard of labour : If poor, will require excessive supervision so that plant will be laid out with this in mind. For instance, a single storey mill will lend itself to a high standard of supervision with minimum supervisory labour.

(7) Fire Insurance : Where a building is used as part mill and part warehouse, different insurance premium rates may apply, and if it is desired to maintain this differential rating, certain machines will be taboo in the declared warehouse space.

(8) Factory Act requirements : Regulations may require the special location of grinding machinery and of dust separating equipment.

The ultimate layout should be characterized as far as possible by :

(1) Compactness consistent with accessibility for maintenance, operation and supervision.
(2) Multi-storey with raw materials occupying all floors at tween operational stages for the particular type of layout concerned ; that is not to say that a single storey layout is to be condemned because of the large amount of elevating required between operations, but that the handling should be a minimum for a single storey plant and similarly for other plants.

The foregoing remarks about plant layout are general to all kinds of industrial plants, and some consideration of their application to compound mills in particular may now be considered. It is not possible to deal with the compound mill at all precisely, unless the cardinal features of the mill flow have been

established. The layout of a plant having bulk storage facilities, completely automatic continuous mixing, and located on a navigable waterway, will clearly differ in detail from that of an inland mill all of whose materials are stored in bags and whose mixing is performed by the manual feeding of batch mixing plant.

In the main there are four principle types of layout:

(1) Multi-storey with raw materials store on upper floors, plant located centrally in the height, and finished goods store at the bottom of the building.

(2) Mutli-storey with raw materials occupying all floors at one end of the mill, plant occupying all floors in the centre of the mill, and finished goods occupying all floors at the other end of the mill.

(3) Multi-storey with raw materials stored at both ends of the upper floors converging upon plant located centrally, and finished goods stored at both ends of lower floors.

(4) Single storey with raw materials, plant, and finished goods all on one level.

Variations in these layouts will be occasioned by the particular circumstances of any one mill.

Fig. 114 shows a layout of compound milling plant that follows fairly closely the flow diagram (Fig. 113). The points of variation being that no molassed meal unit is shown, some of the machines are different from those indicated in the flow sheet and there is no bulk storage capacity.

For the sake of clarity, most of the auxiliary plant items such as electric motors, drives, cooling fans, etc., have been omitted.

The mill is shown as having two enclosed cartways running underneath the length of the building. The island between the cartways carries the feed points of a number of sack elevators and the delivery tables (not shown) of a number of spiral chutes which are used as floor to floor chutes for raw materials and discharge chutes for finished products.

Finished meals are shown stored with the cubes; actually, a considerable amount of finished meal could be stored on the floor above where it is sacked off. It will be noticed that the pulverisers housed on the cartway island can be fed from a number of floors.

The kettles shown in the meal plants are only used in the event of molasses being included in the mixing, but in the absence of molasses, would normally be by-passed.

It will be realized, of course, that the layout shown is merely one of a number of possible ways of dealing with the plant shown in the flow sheet and is not necessarily the best.

Students at this stage are not so much concerned with layout from the mill designer's point of view as with obtaining some idea of layout of plant as found in practice, and herein lies a difficulty.

Compound milling is not at the stage of development reached by flour milling. Flour mills display a substantial degree of similarity in the main lines of their plant layout, whilst it is doubtful if any two compound mills in the country can be considered to have the same layout. This is altogether apart from the differences occurring due to peculiarities of site, etc. If two flour mills of similar size were built upon similar sites, the resulting mills would be found to display considerable uniformity. Two compound mills, on the other hand, might quite reasonably be as different from one another as they are from the flour mill. This is due, amongst other things, to the fact that flour mills are largely designed by flour mill machinery manufacturers, and although they may be acting upon the instructions of the miller, they will also build mills for other millers and the characteristic of the manufacturer will show itself in all the mills he builds. Compound mills are almost invariably designed by people associated with or employed by one firm of compound millers.

In the course of a lifetime, only one mill may be designed by the miller with his engineer, and different contractors will supply different parts of the plant having no interest in the complete specification. It is easily recognized that this individualism will tend to produce mills varying one from another almost as completely as the individuals who designed them. No doubt, as the industry is opened up, in the sense of its principles being formulated and knowledge of them broadcast, a considerable degree of uniformity will become noticeable, but certain characteristics suggest that marked distinctions between mill and mill are likely to be found for a long time ahead.

In the face of this diversity, the consideration of a single layout is of strictly limited usefulness. The comparison of a number of layouts would be better, but even here, common traits would not be found easily and the student might easily find such comparisons confusing in their apparent contradiction one of another. This confusion would be most marked if the comparison was made between the locations of plant items, and it is suggested that the proper approach should be the valuation of each layout by reference to certain criteria.

These criteria may be expressed, in the first place, in more or less abstract terms like flexibility, compactness accessibility etc., but which may be developed to a point where more tangible and concrete conceptions are possible. For example, "accessibility to supervision" might be considered a desirable feature of the ideal layout. If, for instance the mill foreman could stand in one spot and from there immediately overlook the whole of the business of manufacture, it could be said that the plant had a high degree of accessibility to supervision, and

arising from this, the plant specification might include a clause to the effect that all items of plant shall be observable from one central spot. The plant designer faced with this requirement might lay out all the plant on one level, in a circle, from the centre of which each separate item could be adequately observed. Assuming for the sake of this argument that the circular layout is in fact the best from the point of view of supervision, we are now in the position to condemn all compound mills whose plant is not set out in a circle, which criterion is at least tangible and definite.

This argument, in spite of its suggestion of facetiousness, does in fact demonstrate a fundamentally sound approach. It is not dictated by custom, nor is it hidebound by convention. The inadequacy of its conclusion is not a criticism of the method, but an expression of the insufficiency of the original premises, for obviously the ultimate layout of any mill is the result of a compromise of many often conflicting requirements. This will be demonstrated by following a logical development of other criteria as follows :

COMPACTNESS.

That the plant shall occupy minimum space. Assuming a given volume for the plant items, the separating space between the items would approach zero and it might be suggested that the plant be erected to the rough shape of a sphere; a sphere being the geometrical figure which has the least surface area for a given volume.

Dismissing this as completely impracticable, a cubic design might be considered as being the next best thing. The fact that this cheek and jowl assembly of plant makes operation and maintenance a tremendously difficult matter is of no moment in the mere achievement of compactness.

ACCESSIBILITY.

This operates in the opposite direction to compactness and clamours for the maximum clearances between machines, etc. It prohibits the location of plant items out of normal reach.

MINIMUM HANDLING.

This does not necessarily mean minimum distance carried, but is more concerned with the number of deliveries to, and discharges from, conveying machinery and in this connexion a man with a truck is considered as a conveying machine. This criterion dictates the installation of very high mills so that the products may flow through the manufacturing process entirely by gravity, after the first elevation.

FLEXIBILITY.

Expressed in terms of variety of alternative flows, in the ultimate dictates that every plant item be connected by handling

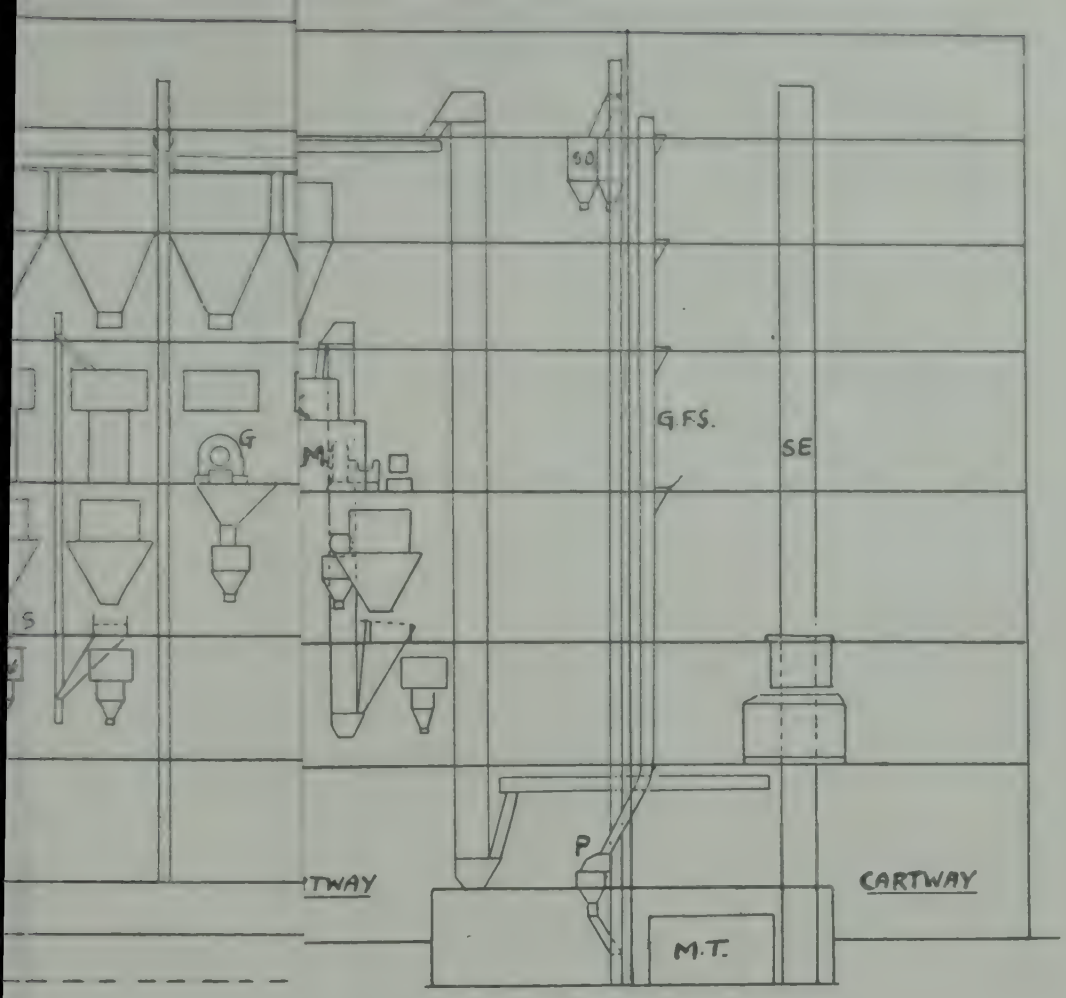
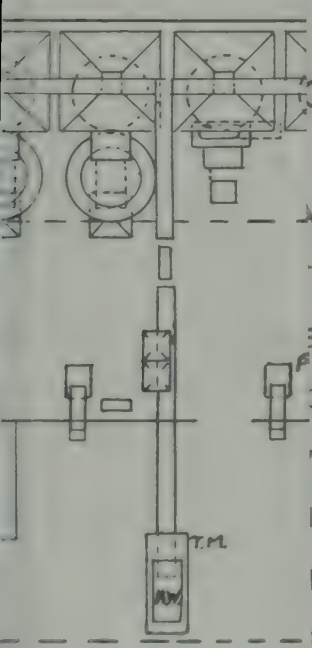


Fig. 114



COMPOUND MILL LAYOUT

KEY

AL BIN		G.F.S.	GRINDER FEED CHUTE
TLE		T.M.	TROUGH MIXER
BING MACHINE		S.E.	SACK ELEVATOR
OLER		S.C.	SPIRAL CHUTE
'E		S.O.	SACKING OFF BIN
TOMATIC WEIGHER		M.T.	MOLASSES TANK
NDER		P.	PULVERIZER
PPER WEIGHER		S.F.	SIFTER

equipment to every other plant item. A mechanical maze. Various other qualities may be considered, but there are sufficient to demonstrate the need for compromise.

Ease of Supervision requires : Circular single storey layout.

Compactness : Spherical or, more practically, cubic layout with minimum clearances.

Accessibility : Maximum clearances with empty headroom.

Minimum Handling : High buildings.

Flexibility : Maximum handling equipment largely idle.

Any one mill will require all these features in varying degrees and the ratio of desirability of each will determine the ultimate compromise.

How are the relative merits of the various criteria to be assessed? The answer is, of course, largely by the resulting cost of production. Layout must lend itself to the lowest possible level of working costs, not forgetting that congenial workplaces have a definite production value.

Students may consider this to be all very theoretical, but it was pointed out in an earlier lecture that the heterogenity of compound milling plant made it necessary to search out basic principles in order to find a common meeting ground for the members of the industry. An indication of the kind of basic principles that govern plant layout is contained in the foregoing; the exhaustive treatment of the subject would require a volume to itself.

One example has been given of the expression of a flow sheet as a practical mill. One version of the continual compromise is represented by Fig. 114; in it, high value has evidently been set on minimum handling (for that type of plant). Ease of supervision and operation is fairly good which usually involves a reasonable degree of compactness. Flexibility is not a conspicuous characteristic, and the mill is evidently laid out to meet fairly constant character of output.

This concludes the present treatment of plant layout, but students may care to note the following points.

Bag intake plant should be so located that the bag is discharged from the transport vehicle immediately on to the elevator or conveyor without intermediate trucking.

The intake conveyor should discharge the bag as near to its store point as practicable.

The storage sites of bagged materials should be convenient to the grinder feeds in the case of those materials that have to be ground and convenient to the proportioning plant feed in the case of those materials received in a suitable condition for mixing. This requirement is easier to specify than it is always to achieve. All grinding plant should be grouped together and isolated as much as possible from the other mill plant, even if this involves additional handling. This

practice limits the effect of explosions, originating in the grinding machines. Pressure reliefs from grinding plant should exhaust to the air outside the mill or into a space having a direct communication with the outside of the mill. In a multi-storey mill, where fire hazard permits, communication between parts of a plant unit located on different floors should be more direct than that provided by main staircases.

Similar machines of any category should be grouped together, as far as possible, to facilitate supervision and the provision of alternative flows in an emergency.

Full use should be made of headroom. Clear floor space is a valuable asset, e.g., an elevator boot that can be located above 6 ft. from the floor is in most circumstances better than the boot being landed on the floor in spite of its apparent inaccessibility.

Storage bins, sacking off hoppers, etc., should terminate underneath the ceiling rather than project into the room above, thus conserving floor space.

Chutes travelling through a floor or several floors should as far as possible be vertical for that part of their lengths within 6 ft. of the floor, any horizontal movement being obtained in the head space unless, of course, the chute is adjacent to a wall.

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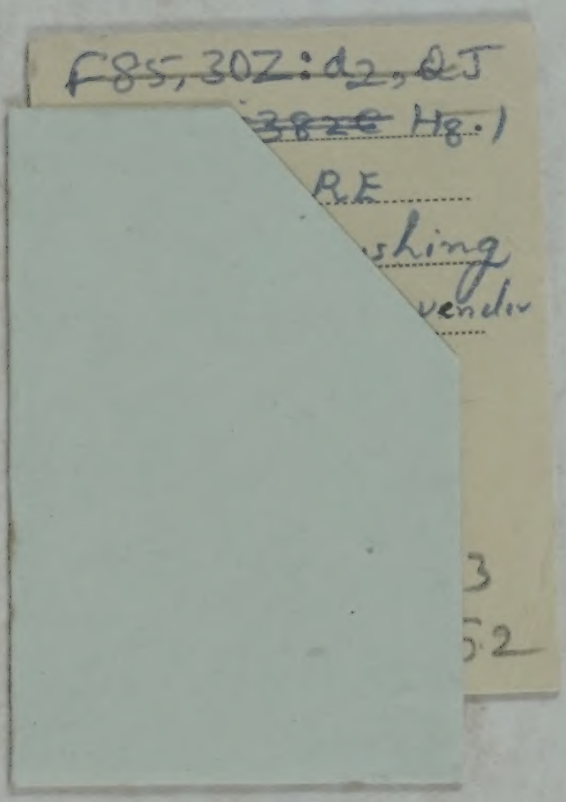
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